Report and Proceedings

OF THE

BELFAST

Natural History and Philosophical Society

FOR THE

SESSION 1917-1918.

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MAYNE, BOYD & SON, LTD., 2 CORPORATION STREET
(PRINTERS TO THE QUEEN'S UNIVERSITY).

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Belfast Natural History and Philosophical Society.

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ESTABLISHED 1821.

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CONSTITUTION.

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BELFAST
NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.

SESSION 1917-18.

11th December, 1917.

"THE FIXATION OF NITROGEN AND ITS APPLICATION TO THE INDUSTRIAL DEVELOPMENT OF IRELAND."

By Professor William Caldwell, M.A., Sc.D., F.I.C.

(*Abstract*).

Dr. Caldwell described, besides other methods, the method of obtaining nitrogen from liquid air, and in this connection recalled the work of Dr. Thomas Andrews, formerly Professor of Chemistry in Queen's College, Belfast, and the work of Lord Kelvin and Joule in defining the principles on which the liquefaction of gases is based.

It was pointed out that we require unlimited quantities of nitrogenous compounds, not alone for use as artificial fertilizers, but for use in the manufacture of explosives. The supplies of the naturally occurring nitrates are decreasing rapidly, therefore we shall have to adopt some method of fixation of nitrogen to replace the natural supplies. Germany's preparations for war were based on the establishment of huge chemical industries, and the foresight of Germany saved that country from defeat after the blockade of Germany became strict.

We may likewise build up industries with peaceful objects in view, to replenish our unproductive soil and to intensify our agricultural pursuits.

In olden times natural manures were sufficient to feed the lands with the requisite nitrogen to be converted into nitrates, previous to absorption and assimilation by the plants and vegetables. Now we must procure artifical fertilizers. One of these artificial fertilizers is procured from the gas works. The coal is destructively distilled and the ammonia evolved is absorbed and converted into ammonium sulphate. But the production of ammonium sulphate in the whole world is relatively a small amount. It was only one million tons in 1910—an amount quite insufficient to meet the demands of agriculture. We must have recourse to Chili saltpetre, a naturally occurring sodium nitrate found on the plains of Chili. For ages the nitrogen of the atmosphere has been absorbed by the soil, and the nitrifying organisms convert it into nitrates.

In 1830 only 935 tons of saltpetre were used from this source, whilst in 1912 2,500,000 tons were used, and 75% of these imported nitrates were used as artificial fertilizers. In a short space of time, however, these sources of supply will have vanished, and therefore we must apply our scientific knowledge to make good the deficiency.

Let us see what methods we may adopt. Plants, belonging to the Leguminosae order, have their roots covered with nodules, which are vast collections of nitrifying organisms, which possess the power of using the free nitrogen of the air and assimilating it in their tissues. At the ordinary temperature without any extraordinary phenomenon these organisms are secreting and storing vast supplies of nitrogen for their own use. Yet these organisms which flourish on the roots of leguminous plants are not specific. They may be cultivated and used by other plants. Land barren and poor in quality may be inoculated with these organisms and made rich and fertile for the production of foodstuffs.

But there is another and more prolific method of fixing the nitrogen of the air. The method was suggested by Sir William Crookes at a conversazione of the Royal Society in 1898.

There exists in the atmosphere, according to a rough approximation, 4,000 billion tons of nitrogen. Over every square yard there are about seven tons of nitrogen. Over every square mile of the earth's surface we have as much free nitrogen which, if converted into nitrates, would manure the lands of the world for a very prolonged period. Crookes demonstrated the fixation of this free nitrogen by passing electric sparks through air enclosed in a specially constructed globe, and showed that the nitrogen was burned and thus converted into oxides of nitrogen which, when absorbed by water or alkali, yielded acids or salts in nitrogen, products ready for use as fertilizers. Crookes pointed out that the experiment might be made the basis of a huge industry destined to solve the great food problem of the world.

A few years later the first successful nitrate factory was established by Professor Birkeland and Dr. Eyde at Notodden, where the artificial production of nitrates is carried out on an extensive scale. Here an alternating current of 3,000—5,000 volts is used, and a powerful electric arc is formed between two copper electrodes placed in a stream of air. The electrodes are hollow to permit them being kept cool by a constant stream of cold water. The terminals are placed about $\frac{1}{3}$ to $\frac{1}{2}$ inch apart. The arc is deflected at right angles to the direction of the electrodes by means of a powerful electro-magnet, placed in such a way that the terminals of the copper electrodes are in the middle of the magnetic field. A great roaring disc of flame immensely hot forms between the electrodes. The gases from the flame are pumped off and yield according to the method of absorption either alkali salts or calcium salts. The calcium salts may be applied directly, without purification, to the soil as a fertilizer.

There is another important method called the Haber process, which has been adopted in countries where water power can be easily obtained When a mixture of nitrogen and hydrogen is subjected to sparks from an induction coil combination takes

place with the formation of ammonia. But the yield of ammonia under these conditions is very small. It has, however, been found that if a mixture of nitrogen and hydrogen be passed over a catalyser—in this case finely divided osium or uranium—heated to a definite temperature, the two gases readily unite and ammonia may be separated in quantities sufficiently large to prove a commercial success.

In 1913 Germany spent £2,000,000 on works to secure the production of ammonia on an enormous scale by this process. The nitrogen is obtained from liquid air, and the hydrogen may be obtained by several interesting methods. Hydrogen may be prepared very cheaply by the electrolysis of a solution of potassium carbonate or of a solution of caustic potash at a temperature of 60°C. The cost is reduced by making use of the oxygen which is evolved at the same time. A second method is to use water gas and to pass it at the required temperature through gauzes composed of catalytic metals, iron, nickel or platinum. The mixture of gases necessary for the production of ammonia may be also obtained from air and steam. The mixture is deprived of oxygen by passing it over heated copper, and then over heated iron to decompose the steam. The oxides of the metals are in turn reduced, and may be used again and again.

Ammonia may also be made from the nitrides—compounds of nitrogen with metals. The process has been developed by Serpek, who uses aluminium nitride, and subsequently decomposes the nitride with the production of ammonia, and aluminium is obtained as a bye-product. The process might be developed in the North of Ireland, where Bauxite, a naturally occurring hydrated alumina, is found in County Antrim.

Again, the carbides, for example calcium carbide, absorbs nitrogen and forms cyanamide. This substance may be used direct as a fertilizer, or it may be decomposed and ammonia obtained under certain conditions.

The cyanamide industry is being developed on a large scale in Germany, France, Italy, Norway, Japan and America.

The fixation of nitrogen may be made by (1) electrical methods or by (2) chemical methods, and although the electrical method, such as the Birkeland Eyde process, requires about 30 times more energy than the chemical method, e.g., the direct synthetical method, yet from the economic standpoint it is not certain that the chemical methods are the better; for, from the point of view of capital expenditure, the arc processes have a good deal in their favour.

Mr. Kilburn Scott has been working on this problem in this country for some years past, and he has devised a special electric furnace for the production of nitric acid, which differs from those used on the continent for the same purpose, in that it is a self-contained three phase unit. The furnace is filled with three triangular metal electrodes. The arcs are struck between the electrodes where they are near together at the bottom, and they are spread out in flames by the flow of air. When the air comes in contact with the rapidly rotating triple arc flames, combination between the nitrogen and the oxygen take place with the formation of nitric oxide. The nitric oxide must be cooled as rapidly as possible, and to facilitate this an arrangement is fitted to the furnace to absorb the heat from the hot gases. And as the hot gases pass away they are used to heat the incoming air. The normal yield of nitric acid is about 50 gms per kw. hr, and with the three phase furnace the yield has been raised to about 66 gms per kw. hr. The other part of the process is similar to what I have described under the Birkeland Eyde system.

Dr. Maxted, on the other hand, favours the method of the direct synthesis of ammonia and its subsequent oxidation to nitric acid, and he estimates that the cost in that case cannot be more than £15 per ton. And he states that so far as power and raw material are concerned the formation of ammonia by direct synthesis is a process more than twice as efficient as the cyanamide process and more than six times as efficient as the arc process. The direct synthesis of ammonia with the subsequent oxidation to nitric acid is by far the most economical means of

effecting the fixation of atmospheric nitrogen. With us in Ireland the product is required as a fertilizer, and in this case it would obviate any risks of loss by accidents to the ships, and indeed it would save much shipping which could be diverted to other uses. We have had to rely on our Navy and its command of the seas for the importation of all our supplies of nitrate of soda, the raw material required to make explosives. On the other hand, the Central Powers have been cut off from external supplies, and have had therefore to develop their internal resources, which they have done to an enormous extent, and if it had not been for this marvellous developmant of chemistry, Germany would have been defeated three years ago.

Since the beginning of 1915 a Committee has been appointed in England to consider these different schemes, and latterly after more than a couple of years, a report has been issued and the Government has made some important recommendations, and some real work has been begun.

To help those who wish to make individual efforts the Government will readily place all their knowledge at their disposal. Some new work has likewise been done on the synthesis of ammonia, and a catalyser has been used which gives excellent results.

Now what can we do in Ireland. Have we any means of providing cheap power? In the first place one should perhaps say that any waste from the gas works, or gas coke furnaces, or blast furnaces should be prevented, because we are just able to obtain about 1/10th of the amount of ammonium sulphate we should obtain if waste was entirely prevented.

It is not a dream to assert that the power is at our doors. If we want water power then on the Bann we have two waterfalls—one at Portna and the other at Mavanagher. They might be used without any very extensive hydraulic work, and would produce between them about 600 H.P. The falls are not high—from 11ft. to 16ft.—but then we must remember that the falls at Reinfelden and Schaffhausen are not any higher. These small

falls on the Bann might be used for the Haber process which requires only a moderate expenditure of power. Nor can the day be far distant when we shall harness the waters of the Shannon, and for Ulster the waters of Lough Erne will one day be conveyed by canal and pipe to some power station for distribution for different purposes for many miles around the province. Again we have other sources of power, and if these can be developed, then Ireland will benefit to a very great extent. Ireland is mainly an agricultural country, and if we could have cheap fertilizers our agricultural pursuits would develop enormously. We are a poor people, and the land is cultivated in a poor fashion. In Germany four or five times the manure we use is put into the soil, with the result that their crops in the past have been more prolific.

For the source of cheap power we turn to peat. The peat itself is a source of nitrogen, and when the peat is carbonized the nitrogen present can be recovered as ammonia, and in view of the enormous peat moors which exist in the world the reserve stock of nitrogen is very great. In Russia there is no less than 95,000,000 acres, in Finland $18\frac{1}{2}$ million acres, and in Ireland 1/7th of the whole country—about $2\frac{3}{4}$ million of acres is bog or peat land. Hence the combustion of the peat itself will produce huge quantities of ammonia sulphate, but the combustion from the peat will also give us a power gas, which can be used for industrial purposes or for the purpose of synthesizing ammonia itself, by the use of atmospheric nitrogen. The problem has been solved elsewhere. The peat gas is produced and utilized, and the ammonia obtained as a bye-product. At Osnabrück, in Germany, the peat gas is used by a central electrical power station, and yields 3,000 H.P., whilst the reclaimed moorland can be used for agricultural purposes. Therefore, a practical use for the peat in this country is to convert it into gaseous fuel in suitable gas producers. In this way you obtain the combustible gases, ammonia, and some other important bye-products. There is a plant of this type in use at Portadown belonging to the firm

of Hamilton Robb, Ltd. This installation is, it seems, very satisfactory, and effects a considerable saving in the coal bill. The bye-products are allowed to go to waste ; nevertheless, it is a commercial success. Recently plants have been devised to recover the nitrogen as ammonium sulphate while the gas is used to drive gas engines, which drive alternate current generators. In another such plant in Italy a total power capacity of over 3,000 H.P. has been obtained, and the gas engines are coupled to alternators. The current transmitted at a tension of 30,000 volts is distributed over an area of 25 miles radius. Therefore, what one would naturally suggest is the establishment of a producer plant at or near the bog land itself, the conversion of the mechanical power into electricity, and the transmission of the energy at high pressure to the point where it is wanted. This method of using the peat, and the recovery of the land for agricultural purposes, may be combined with some of the methods for preparing or synthesizing ammonia or nitric acid, by the use of atmospheric nitrogen. Our fertilizers will be produced in abundance, our lands will yield accordingly, and our people may have such prosperity as a result of the enterprise, as to cast discontent aside and become as happy, as contented, as enterprising as our fellow-countrymen in the North of Ireland.

8th January, 1918.

THE GIANT'S RING.

By Mr. H. C. Lawlor, M.R.I.A.

The Giant's Ring, situated in the townland of Ballynahatty and adjoining those of Edenderry and Ballylesson, some four miles south-west from Belfast, may well be classed among the most remarkable earthworks in Ireland. It is somewhat smaller than Tara or Emmania, covering some ten acres, but it is distinguished by containing a very fine Cromlech almost in the centre, a feature which makes it, I think, almost unique in monuments of the sort. Mr. Borlase states that another example of a Vallum or Rath surrounding a Dolmen is that of Leacht an Scail in County Kilkenny, but in this case the ring has been levelled.

Another individual peculiarity of the Giant's Ring is that whereas in all other cases that have come to my knowledge the mounds or walls of ring forts or raths have always been formed by heaping up the soil dug from a surrounding trench; in this instance there is no foss round the Vallum, and no sign that there ever was one. The question naturally arises, where then was the vast quantity of material necessary to build the mound got from? I shall refer to this interesting question later.

Unlike Tara, Emmania or Newgrange, the Giant's Ring is completely without a vestige of written history. The complete removal from the whole district of all trace of the old inhabitants, through English and Scottish plantations, has also removed any oral traditions that might have been handed down concerning it. The names of the townlands in which it lies or which it touches, Ballynahatty, Edenderry and Ballylesson, convey no hint. True, Dr. O'Donovan suggested that Ballynahatty might resolve itself into Bally n'ait tigh or the "Townland of the site of the House,"

or that it was in prehistoric times the residence of a Sept called O'Hatty. Ballylesson in its present form is merely the townland of the small lis or fort. This cannot apply to the Giant's Ring. Two other suggested interpretations of Ballylesson have been put forth : one that it is a contraction of Bally-lis-owen or the townland of the lis of Owen ; the other that the 'an' or 'on' terminating the word Ballylesson is a modern contraction from the old Irish Oenach or festival with games, and that the name means the "place of enclosure of the games." This translation is very tempting, but unfortunately does not lend itself to gaelic etymology. The form of the name of this townland in the 17th century inquisitions was Ballynalissan. We may assume that the Bally is comparatively modern, say mediaeval, but unfortunately we cannot up to the present trace any earlier reference to the place in ancient literature. If it is referred to, as it may be, it is by some name that has not yet been identified as applying to it.

The townland of Edenderry, "The slope of the oak trees," touches on the Ring on the south side. The oak tree has always been associated with Druidical worship. Some sixty years ago a few stunted oaks still remained on the Giant's Ring, and it is quite possible that they were the descendants of an ancient grove of oaks connected with Druidical ceremonial.

The Vallum is divided by seven depressions into seven arcs. That these are part of the original design there can be little doubt. Mr. Borlase in his description of the Ring refers to this fact, and points out that similar depressions or gaps are a notable feature in certain very similar and even larger prehistoric enclosures in Ohio, known as the "Mound builder's works."

It is curious that from one spot only outside the Ring can a view be had of the inside ; this is a certain point on a ridge about 100 yards from the vallum on the north side, and on the spot is an old thorn bush known locally as the fairy thorn. It lies N.E. of the cromlech.

The fascinating mystery of this ancient monument has for

generations excited the curiosity of many people of historic and antiquarian tastes. Within the last few years it has been placed under the guardianship of H.M. Office of Works, who have ample powers to protect it from destruction.

In the early part of last year I had an interview with the Board, and laid before them the fact that a number of local gentlemen would be willing to provide the funds necessary to investigate and excavate the Ring if the Board would give them permission. They advised us to form a local committee who would be responsible for the proper carrying out of the work under their supervision, and guarantee that no injury would be done to the structure, and that everything would be left as we found it, and that any antiquarian remains found would be handed to the local Museum. The necessary preliminaries having been satisfactorily arranged, a liberal sum was contributed towards the expenses, and work was commenced on Monday, the 10th September. I have to acknowledge the kindness of Mr. Gray and Mr. Thompson, the tenants in possession of the Ring, for their permission to make the excavations, and for their help in many ways in forwarding the work.

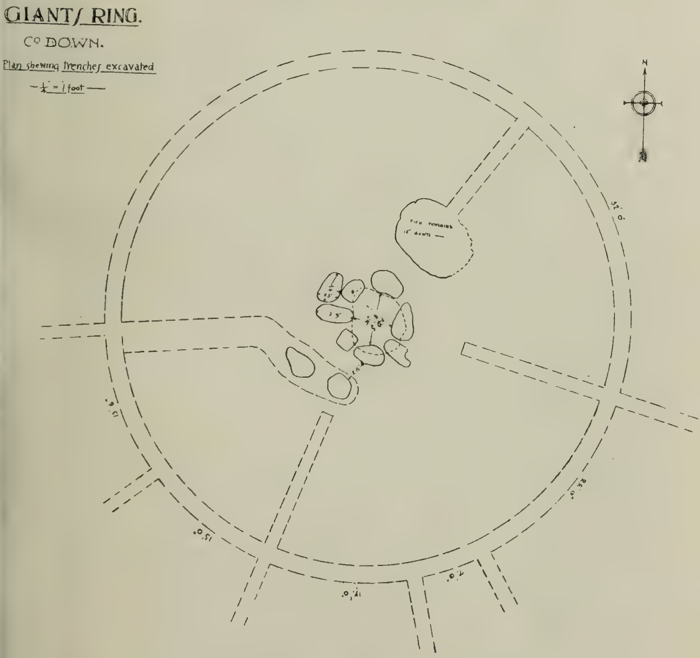
The vast extent of the Ring of course prevented any thought of excavating it all over, so we decided to sink trenches radiating from a small circle round the cromlech. In dry weather in certain places in the Ring the grass dries up and yellows in patches, suggesting the presence underneath of stone slabs or hollow cavities as the cause. Several of these were noticeable in a line running east of the cromlech, so we began the first radial trench, No. 1 in the plan, to cut through some of these patches. We found the undisturbed till to lie evenly 15 to 18 inches under the surface, being of the glacial deposit common in the whole basin of the lower Lagan. The yellow patches were not caused by slabs of stone as we thought possible, but merely by some extra porous spots in the gravelly nature of the till. We extended this trench to the inner edge of the Vallum, but nothing in the way of archaeological remains rewarded our

search. The trench was accordingly filled in and carefully resodded. The same negative result awarded our excavations of trenches 2 to 6, the only noteworthy feature being that while the depth of the undisturbed till below the grass was mostly 15 to 18 inches, at the outside end, as we approached the vallum the surface of the till descended somewhat steeply. Thus the surface of the till underneath the soft top soil of the surface of the whole enclosure resembles the shape of an inverted saucer, of which the centre is some 10 feet higher than the edges. The depth of the soft top soil at the outer edges increases to from five to six feet deep, so that the visible surface also has the inverted saucer shape, although to a much less extent.

The circular trench round the cromlech was dug so as to approach the latter not nearer than 20 feet. In it nothing of interest was found, and all were filled in and resodded. Our object in sinking the circular trench so far from the cromlech was to avoid any possibility of loosening the foundations of the great stones. This caution was necessary, as had there been any previous disturbance of the firm till in the immediate vicinity of the stones, such as the presence of a cist or urn chamber, there would have been some danger in excavating to any depth too close to the stones. As the work proceeded, however, it became evident that there was little danger, as the upright stones are well and truly set on the hard till, and no cist or chambers exist round the outside of the monument. We sank narrow trenches radiating inwards from the circular trench without finding anything of note, except at one point only. In the trench north-east of the cromlech we found at 15″ down, spread on the hard till, a layer of brown black sooty remains of fire. We followed it until it disappeared, exhibiting the fact that it only extended some three feet in diameter, with a depth of only about one inch. The fire remains were evidently extremely ancient, as it required a glass to see that they contained fragments of burned wood. No remains of bone could be detected in the black soil, but a stone hammer, the only implement or fragment

of implement or utensil discovered in our researches, lay in the fire remains. In all our investigations we found no single vestige of pottery, no pieces of worked flint or shaped stone, only this one elongated oval stone chipped at each end by hammering some object.

The accompanying larger scale plan of the immediate vicinity



of the cromlech shows the position of the stones as they remain to-day, and also the places where we excavated. It is of importance to draw a distinction between the stones that are set on the

hard till and those that lie only on the surface. The original supporting stones are all set on the hard till. One very large stone stands upright, leaning against the main structure on the north side, but it is not set on the till. There can therefore be no doubt that it was originally a second top stone of the cromlech itself, fallen down through original faulty erection, or more probably by the action of modern destructive hands.

The earliest known description of this cromlech is that in *Harris' County Down*, published in 1744. If his description is correct, the monument has suffered much since then. He says: "It consists of one huge upper stone, almost round, 7ft. 1in. by 6ft. 11ins.; two ranges of rude pillars support it, each consisting of seven, and round it at about 4 feet distant are several fixed stones not above two feet high."

The possibility of the correctness of Harris' account has been called in question by a writer in the *Dublin Penny Journal* as long ago as 1834. Mr. Borlase thinks that Harris' account was probably correct, and that the outer ring has been removed for building stone. The removal of these seven stones of the outer ring might account for the fall of the second top stone now lying on its edge on the surface of the top ground; but Harris mentions only one top stone, the one that still remains in its place. It rests actually on three stones, not on seven, though there are seven upright stones besides the fallen top stone. The "several fixed stones" (now two in number) "not above two feet high at about four feet distance" are still there. Now the nearest one of these to the uprights of the cromlech is only 2ft. 6in. therefrom, whereas Harris says 4 feet from the alleged outer row of seven stones. Had there been such second or outer row of seven stones they would actually have touched this smaller stone, not been 4 feet from it as Harris states. Had builders come to quarry stones for their work from the cromlech it is inconceivable that they would not have first taken these two comparatively small outlying stones which could be easily lifted; as the monument now stands, and as it appears to have stood in Duberdieu's time,

and I think probably in Harris' time, it consists of one top stone in position, one top stone fallen and seven upright stones, besides the two outside disconnected stones, or eleven stones in all. Mr. Borlase says "there appear to have been two covering stones, one of which has fallen owing to the removal of the side ones." Yet Harris in 1744 says there was only one top stone, although he says the alleged side stones were then in position. So that in this detail Mr. Borlase seems to contradict himself. On the whole I think the evidence tends to prove that Harris' account is inaccurate, and that the cromlech remains almost in its original form, except that even prior to Harris' day one of the top stones had slipped down to its present position from the top of the three upright stones it lies between, which would still support it if raised up.

Having closed up and re-sodded all the excavations near the outside of the cromlech, we proceeded to sink a narrow shaft under the cromlech itself. This excavation proved that we had been forestalled by someone who unfortunately never seems to have placed his discoveries on record. The soil was quite loose, and at nearly four feet down were fragments of modern lemonade and porter bottles. Every spade full of soil taken out was carefully examined. A few fragments of burned human bones occasionally appeared, not a teacup full in all. Whether the previous explorer had found an urn containing bones, or merely found burned bones buried in soil, there was nothing to indicate. Not a fragment of pottery was forthcoming. Had the previous investigator found an urn full of bones and taken it away, why would bones be found through the loose soil? On the other hand, if he had found merely bones buried in soil, he may have removed a portion of them, and what we found were the remainder, reduced in quantity by decay more rapid after his turning them up. I have made enquiries in every direction I can think of as to the existence of an urn from this site, either in museums or private collections, but can find no trace of such. There may have been one, but from my experience gained in the

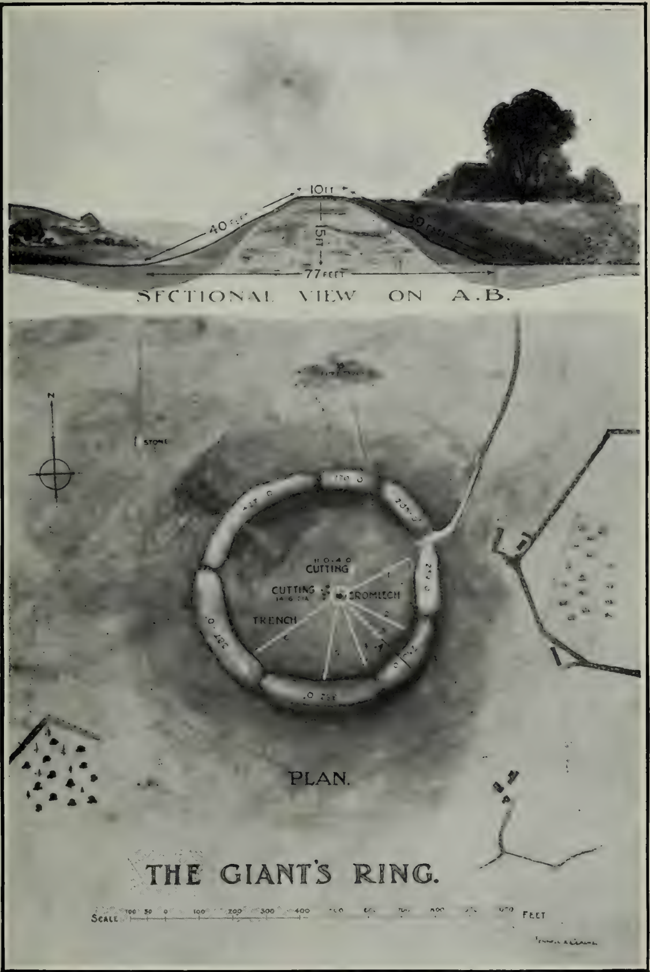
investigation of the Cairn Grannia at Mallusk, I am of opinion that the interment in this dolmen was one of incinerated remains in the soil under the cromlech without an urn. In the Cairn Grannia there are nine distinct cromlechs joined together in a line. In each one examined the burial was of incinerated remains in the soil ; two urn burials were found, but they were evidently of later date and not under distinct cromlechs. As I have mentioned, the Giant's Ring cromlech is not in the geometrical centre of the Giant's Ring, but some eight or ten yards to the south-east of that point. We ascertained by accurate measurements the exact centre of the ring, and sank a circular pit five yards in diameter there. The hard till was 15 to 18 inches beneath the surface, and this excavation was entirely negative in results. We also dug several other pits where we thought slight hollows or dry patches existed, but had no better results.

Our original intention had been to continue the sinking of these radiating trenches all the way round from the cromlech, but as the results obtained in the excavations already made were so completely negative, we decided to discontinue further excavations in this direction. In all we had excavated nearly 600 yards of trenches of an average depth of about 18 inches down to the undisturbed till. With the exception of the remains of a small fire and a stone hammer lying a few feet north-east of the cromlech, not a single thing was found in excavating outside the cromlech to indicate that the site had ever been occupied in any way by man.

It may be urged that our actual excavations only covered, in all, some 400 square yards out of a surface of some 10 acres, and that we might easily have missed valuable discoveries ; which may be perfectly true.

The final excavation we made was to cut a trench two-thirds across the mound itself down to the original ground level, some 15 feet in depth and 4 feet wide.

The accompanying section of the mound, kindly prepared by Messrs. Fennell & Clarke, admirably shows the dimensions. The


10 FT
40 FEET
39 FEET
15 FT
77 FEET
SECTIONAL VIEW ON A.B.
N
STONE
CUTTING
CUTTING
CROMLECH
TRENCH
PLAN.
THE GIANT'S RING.
SCALE
FEET

material of which the mound is made is chiefly small roundish boulders covered with an outside layer of earth and sods. A certain amount of earth has filtered down from the outside among these stones, and in places among boulders were pockets of earth. The boulders were of the glacial deposit type characteristic of the locality. It is, however, a remarkable fact that we found no large stones; all were small stones of which an ordinary man could easily carry one or two in his hands from some distance. Now, had this circular mound been made by removing the top of a knoll in the centre, large stones would have been plenty, as we found numerous large stones in course of our excavations, and they are of frequent occurrence in all these glacial deposits in the immediate neighbourhood. One is therefore forced to the conclusion that the material from which the mound was built was carried by the hands of a large number of workers from the country round, and that the almost flat or slightly convex enclosure is in its original shape.

It would be futile to conjecture now who were the builders; were they bands of slaves owned by the surviving relatives of the great and important person buried in the cromlech? or were they voluntary tribesmen who, out of respect to the memory of the deceased, continued to carry stones to cast them on the mound as they passed until it gradually assumed its vast proportions? I rather think the latter is the more probable, as had slaves been employed, they would not likely have heaped up only small stones; again, the ancient Irish custom of passers-by throwing a stone on the cairn of some deceased chief or king is well known. The division of the mound into seven distinct arcs or sections may also suggest that the work was done by seven separate tribes owing allegiance to the deceased. The measurements of these arcs might accordingly be an indication of the relative sizes of such tribes, and it may be of interest to record the length of the sections. The following are the measurements, commencing with the section to the left of the entrance, and measured

along the top of the ridge :—259 ft. ; 250 ft. ; 382 ft. ; 387 ft. ; 427 ft. ; 170 ft. ; 205 ft. ; total, 2,080 feet.

The measurements of the enclosure to the bottom of the inside of the mound are east and west 599 feet, north and south 588 feet. The average width of the mound at the base is about 80 feet, so that it will be seen the Ring is almost, though not quite circular, with a diameter over all of about 250 yards.

I have referred to the great depth of the soft top soil covering the hard boulder clay immediately inside the mound. This is carefully shown in the sectional diagram, and proves that originally the mound was at one time considerably higher, a great deal of soft mould having been worn down by weather and spread over the ground at the bottom.

It is noteworthy that in the immediate vicinity of the Giant's Ring numerous antiquarian remains have from time to time been found. Thanks to the painstaking work of the late Mr. McAdam, editor of the original *Ulster Journal of Archaeology*, and the late Mr. Getty, an account of these, so far as they could ascertain particulars in the year 1855, was published in that Journal.* Fortunately the farm immediately to the north side of the Ring was then in possession of the late Mr. David Bodel, representative of a family who had been in continuous occupation of the farm for at least three or four generations. Mr. David Bodel and his father before him took an intelligent interest in such matters, and although in agricultural improvements to their farm they had destroyed many ancient monuments, Mr. Bodel was able to supply Mr. McAdam with a pretty full description of such of these monuments as he had either seen or found himself, or his father had described to him.

One of these was discovered by Mr. Bodel in 1855, and I take the following from Mr. McAdam's article. This ancient sepulchral Chamber lies almost due N.W. of the Giant's Ring, about 4/500 yards distant, in a small plantation of Scotch fir at the west end of the farm house. The floor of the Chamber

* Vol. iii, p. 358 et. seq.

is about five feet below the surface of the ground, and is three feet high in the centre. The depth of the top of the roofing stones below the surface is 18 inches. In the Chamber when found were four urns containing burned bones, besides a number of skulls and other bones, human and otherwise, some burned and some not. The urns were too fragile to preserve ; the bones were removed by Mr. Grattan for examination. After examination the Chamber was carefully closed up, and remains, I believe, still intact.

Of the other remains of which Mr. Bodel supplied a description, I shall quote from Mr. McAdam's article.

> " In addition to the facts observed upon the present occasion, it may be well to record, upon the testimony of Mr. Bodel, that the field in which this discovery was made forms part of a farm held by him and his family for several generations ; and that, on various occasions, he and his predecessors have discovered throughout the same piece of ground indications of extensive interments ; vast quantities of human bones have been turned up by the plough, both in his own time and that of his father, especially in the vicinity of the present dwelling-house. In the boundary fence of the field, facing the Giant's Ring, is an enormous stone which he suspects to be a Cromlech, and intends to have uncovered. Very near this spot there were taken up in the field, a little below the surface, many cartloads of human bones, but without there being any mound or mark to distinguish the place. On the site of the dwelling-house itself, which is not many perches distant, was a mound, which on being removed at the time of building the house, disclosed several short stone coffins or cists containing earthen urns and burnt bones. In several parts of the same field similar cists were found subsequently, all formed of stone slabs, and having a slab at the bottom and one as a lid. These in most cases contained urns. The coffins were all shorter than a man. In one of the urns was found a skull by Mr

Bodel himself; in each of two others bones and a stone implement. One of the implements was minutely described by Mr. Bodel as a black stone 6 inches long, knobbed at each end and hollowed between, with a small hole passing through the centre of the intermediate stem. The other was a yellow stone tapering at each end, almost resembling in size and shape a gimlet head, and pierced in like manner at the centre with a small hole. In another urn, along with the usual burnt bones, were two flint arrow heads. Occasionally stone axes have been found in the field. At one extremity of it, furthest from the house, there was a spot several perches in extent, on which the vegetation was observed to be always bad. On digging it up it was found, for several feet deep, to consist of a peculiar dark-coloured and soapy mould, and intermixed with it were observed a number of red stones, presenting the appearance of having been discoloured by strong heat. Near this spot was a small mound, somewhat elevated; and about fifty or sixty years ago (i.e., about the year 1800), Mr. Bodel's father, having an idea that he might find something valuable within it determined to open it. On removing the earth a little he came to some large blocks of stone standing upright, and was then fully persuaded that his hopes would be realised. He therefore removed the entire mound, and found it to contain three very large stones placed on end and sloping towards each other at the top. On examining underneath this enclosure he found an urn and a quantity of small bones, but nothing further. In the same part of the field were found four rings made of a black light substance, like jet, the largest about four inches in diameter, and the other three smaller, in regular succession, the whole of them fitting exactly one within the other, so that when thus placed they presented the appearance of a circular grooved disk. In one part of the field Mr. Bodel pointed out a spot where a pillar stone was buried some years ago in clearing

the ground. Some coffins and urns, exactly similar to those in Mr. Bodel's field, were found at different times in the adjoining lands held by Mr. George Thomson, Mr. McKeown, and Mr. Frederick Russell ; and there was at least one artificial Chamber discovered resembling the one now described."

In Arthur Young's "Tour in Ireland," published in 1780, the author refers to a mound close to the Giant's Ring, in which had been found on its removal vast quantities of human bones. He does not indicate how long before he wrote, this discovery had been made ; he may refer to the mound which had occupied the site of the farm house mentioned by Mr. Bodel, or possibly yet another sepulchral mound. Father O'Laverty in his "Down and Connor" * refers to a funereal mound in the grounds of Edenderry House, lying south-west of the Ring, in which Urns have been found.

It is worthy of note that in these various accounts of past discoveries in this district, particularly in Mr. Bodel's graphic narrative, while many funereal urns, wholesale internments in mounds, various stone implements and other remains have been found, not a single instance is recorded of the discovery of ancient bronze or other metal.

Bearing upon Harris' statement that in his day, 1744, the cromlech had two rings of seven stones each, or 14 stones in all supporting the top stone, it is important that Mr. Bodel, who was able to describe to Mr. McAdam in 1855 so much of what had happened to the various ancient monuments in the locality for three or four generations, probably back to Harris' time, makes no reference to the removal of any stones from the cromlech ; it is inconceivable that Mr. McAdam and Mr. Getty should not have made enquiries from Mr. Bodel on this point, and recorded anything he had to say.

During our investigations, which extended over a week, we had the benefit of the presence and advice of several distinguished

* Vol. ii, p. 240.

archaeologists, of whom I may mention Professor R. A. S. MacAlister, Mr. Andrew Robinson, of H.M. Board of Works, Canon Lett and others. Professor MacAlister has been good enough to write the following on the result of the investigation:—

NOTE BY PROFESSOR R. A. S. MACALISTER, M.A., D.LITT., F.S.A.

"That no antiquities of any kind were discovered in the Giant's Ring is not surprising, having regard to the probable nature of the Monument. Indeed, from one point of view the negative result is not unsatisfactory, as it is an indication that the study of this and analogous monuments, after many and devious experiments, has at last settled down on proper critical lines.

That the monument was primarily sepulchral may be taken for granted ; also that it belongs to the Dolmen building period. That is to say, it dates from the time of the overlap between the stone age and the bronze age, though probably a little nearer in date to the former than to the latter period, i.e., early in the time of overlap.

There is no doubt that the stone monument in the centre of the ring was erected over the sepulchre itself, the structure being designed, like all dolmens, after the model of a house. It is, indeed, the "eternal house" provided for the use of the soul, in which food and the offerings could be provided from time to time.

The stratum of burning found in a patch immediately to the north-east of the Dolmen, may possibly mark the site of a dwelling, perhaps the actual dwelling of the deceased, though this of course can only be a matter of conjecture.

The mound of earth and stone surrounding the Dolmen (1) is undoubtedly connected with it, (2) is not the rampart of a residential enclosure, for in that case pottery and other signs of occupation would have been found within it. The total absence of any such objects, and the absence af any signs of disturbance of the soil for graves or any other purpose (excepting recent tillage) is an indication that the enclosure within the mound was

not only not occupied, but was actually avoided. We are in the presence of a religious taboo of some kind.

It is not difficult to guess the reason of this taboo. The ground surrounding the Dolmen is sacred to the spirit of the dead person ; no unauthorized intruder dare tread upon it. At the same time the fence protects the living, preventing the ghost from breaking bounds and coming out to injure them in any way. Modern savage life presents analogies with both these forms of belief.

The modern superstitions connecting fairies with ring-forts of this kind are survivals of this dread. Some of the so-called ring-forts are probably at least primarily, sepulchral ; and fear of the ghost, degenerated in more modern times to fear of the fairies, has prevented intruders from trespassing upon them even to our day. These sepulchral ring-forts (if I may use this not very scientific expression for convenience) are essentially of the same type of monument as the Giant's Ring, differing only in their inferior size. The unusual size of the Giant's Ring may be confidently taken as an indication of the great and important rank which the person commemorated by it held among his contemporaries. He was most likely deified after his death ; and the tradition of horse races and other games held in the Ring till modern times may well go back to the games and processions that we may presume were held there periodically in his honour. In this connection it is worth noticing that to the north of the Ring is a ridge from the highest point of which (and from nowhere else in the immediate neighbourhood) a view of the interior of the Ring can be obtained. On this view point stands a thorn tree, suggestively called the fairy thorn, though the ridge in question, I am satisfied, is quite natural. That the exact nature of the interment was not discovered in the recent excavation can be sufficiently explained by previous looting. Such a monument as this would be sure to attract the attention of treasure seekers as soon as the dread of the Ghost had ceased to influence the population.

Like Stonehenge, the tomb sanctuary became the centre of a bronze Age cemetery, the graves of which were scattered around, *but not inside* the Ring.

The nearest analogy to the Giant's Ring burial that I can quote, in Ireland, is the Bronze Age Sepulchre excavated a few years ago at Longstone Fort, Furness, near Naas, County Kildare.* There was at this place an earthen ring similar to that surrounding the Giant's Ring Dolmen; at its centre was a subterranean cist burial, marked by a tall standing stone. Traces of extensive burning were found around the cist: these the explorers interpreted as the marks of a peat fire, probably lit for a beacon to summon the clans to the burial of the chieftain.

The excavation has thus proved that the Giant's Ring was a tabooed grave sanctuary, into which intruders were not admitted (except perhaps on the occasion of games or other religious celebrations); sacred to the spirit of some great chief, medicine-man, or other notable functionary, of the end of the Stone or beginning of the Bronze Age (say very roughly, about 2,000 B.C.). The gigantic nature of the structure makes it certain that the deceased was a personage of outstanding importance; and suggests the probability that the work was carried out to his own plans and during his lifetime, though this again is naturally conjecture only. But it is not unlikely that he might compel his followers to erect the structure under his own superintendence in order the more to impress his own importance upon them.

* Proceedings Royal Irish Academy, vol. xxx sec. C. p. 351.

12th February, 1918.

THE FOLK-LORE OF NORTH OF IRELAND PLACE NAMES.

By Sir John Byers, M.A., M.D.

(*Abstract.*)

After pointing out the importance of the study of place-names, not merely as to their origin, but also in regard to the curious sayings, homely proverbs, and rustic rhymes associated with them, Sir John Byers said certain broad principles might be laid down to form a guide in their investigation :—

First—Many place-names are not only very ancient, but also remarkably permanent.

Second—Place-names, in their origin, are, as a rule, simple, and show sympathy with nature.

Third—Place names are often primarily most utilitarian, except in the case of religion and superstition.

Fourth—In the history of almost all countries, and especially so in the case of the northern parts of Ireland, various bodies of people—colonists and conquerors—came at different times, each speaking a mother-tongue of their own. Now, not only did these invaders bring place-names peculiar to themselves, but they also adopted and often altered others already existing.

Fifth—Place-names are, in many cases, compounds made up of a substantive or generic term, and a correlative, indicating some attributive quality. In pronunciation, the stress or emphasis almost invariably remains on the qualitative syllable, and this, in English place-names, usually precedes the other, while, on the contrary, in Celtic words, the qualitative usually follows the substantive.

Sir John Byers illustrated each of these principles by numerous examples, and gave a selection of proverbs, sayings, and rhymes associated with a large number of North of Ireland place-names.

12th March, 1918.

THE PSYCHOLOGY OF TELEPHONY.

By Mr. John Lee, M.A.

(Abstract.)

The true student is always working at experimental psychology. The working of the human mind is the most entrancing subject, and wherever we are we can watch its operations. The waiter in Mr. Bernard Shaw's early comedy asked us all to watch the working of the barrister's brain. But not only barristers have brains, and the true experimentalist will wish to gather his data from a wider field. He will be interested in the human mind normally, so to speak. He will watch carefully when any factor comes into the normal life which will enable him to study the human mind afresh. Now I am about to claim that the telephone is such a factor. It will be my effort to show that some of the fundamental problems of psychology are capable of fresh consideration by reason of the data which the use of the telephone has placed at our disposal. For the telephone was something more than a new instrument of communication ; it was a revolutionary change in our method of communication ; the telegraph was less revolutionary. The written message still obtained, not essentially different from the written message which we put carefully in an envelope. It was more brief, more blunt. It eschewed the pretty politenesses of the ready letter writer, the "kind regards," the "Yours faithfully," the "best love to all," and "hope to find you well as it leaves me at present." It went to the point without fuss or flummery. But the telephone wrought a revolution. It brought us back to the courtesies of speech ; it threw the cumbrous art of handwriting overboard. It called on us to face each other direct and without intermediary, and so it affected our mental relationship. Deep called

directly unto deep. And so it came about that the rector of a distant Yorkshire village, what time he spent his leisure making the telephone into a practicable means of day-by-day communication, really wrought more wisely than he knew. He really set out to put the human mind to a severe test, for the human mind had grown accustomed to the written word as its means of communication, and not readily, as I hope you will see, did it fit itself into the new conditions. Telephony is only at the beginning, we have heard again and again, but I think it is nearer the truth to say that the human mind in its appreciation of the differences which have been wrought by telephony is only at the beginning.

To begin with, we have not grasped the central fact that the telephone annihilates distance. Whatever may be our explanation and our theory of the Kantian categories of time and space, the fact remains that the telephone illustrates how deeply the framework of space is upon our minds. It is shown in the first place by the way we bawl into a telephone. That comes from the idea that the persons to whom we are speaking is far away. We shout as if we were shouting at them across a valley. The fact is that the people are very near to us. They are so near, in fact, that in auditory efficiency they are only a few feet. This is proved by the use of the telephone for persons with inefficient hearing, where the telephone actually is only a few feet distant. But our mental framework is such that we cannot bring ourselves to realize that the telephone has annihilated distance, that it has broken down all walls and barriers, that it has given us a whispering nearness to the person to whom we are speaking. Which of us, using the telephone, realizes for a moment that our lips are to our friend's ear? That puts in a phrase the fact that we have but little conception of what the telephone has done in the annihilation of space.

Now let us examine the content of this conservative psychology. In the first place the phraseology which we use is based on the emphasis of distance. It is as though we thought

we are still speaking with two tin cans and a drum of parchment, now shouting at the parchment and now turning our mouths away and shouting through the pure air, "Could you hear *that* Bill?" The favourite phrase is "Are you there?" It is an emphasis of distance, a puerile phrase, an indication of vacuity of mind, for indeed we should shudder if the answer "No!" came along. The word "Hello!" which is regarded with disfavour nowadays, took its origin in the convenient shout which made the hills resound. We need other phrases, but much more than that we need the psychological realization that the person to whom we are speaking is close by. Until we get this psychological realization we shall never use the telephone efficiently. No matter how Science may improve it, no matter how clearly and distinctly the newer receiver may give us the distant voice, so long as we have the framework of distance and of wonder as the primary outfit of our minds, just so long shall we shout "Hello!" and "Are you there?" and so long will the telephone continue to be a tin can and a parchment diaphragm.

This conception of distance vanishes from the mind of the expert. I could show you a group of ladies speaking with infinite ease from London to all the great towns of the country. They pass from the Brighton subscriber to the Liverpool subscriber with infinite ease. They speak in a soft, subdued voice, a trained voice, as if they realized the new intimacy. They are not overwhelmed with the wonder of the thing; they are taught to harness the lightning and not to shudder at it. They will say "Liverpool" with a rising inflexion, which means "Please tell me, Liverpool, if you are within earshot;" they will reply "Liverpool" with a falling inflexion which says: "I am in attendance; I am Liverpool and not Newcastle-on-Tyne"; but it does not say or suggest "I am *at* Liverpool, two hundred miles away." That intimate and trusting use of the telephone needs to be cultivated and then the telephone will be really useful, but it is not done in a generation. The framework of mind to which we have grown accustomed is not readily changed. The

psychology of adaptation to habit throws its tyranny over us and holds that tyranny fast for many a generation.

This is why we use stilted speech and why we shrink from intimacy. We speak in the mode of the writer rather than in the natural mode of the speaker. We labour under the burden of distance, which is always present with us, and we speak on the telephone, as Queen Victoria said of Mr. Gladstone, just as if we were addressing a public meeting. The personal nature of a telephone conversation has not yet been grasped. Of this fact we can see various evidences. The telephone is used outrageously in the drama. The speakers bellow through the instrument, and their conversation is a repetition of what the other fellow says:—"Mayfair 1861, that you Jimmie? Oh, you are going to catch the 12-30 to Bournemouth, are you? Ah, it will be a very pleasant day. Yes, I like the Royal Hotel, too." There is a typical stage conversation It includes what Jimmie said and no more. In fact it is designed to convey what Jimmie said and nothing else. It is the crudest of stage conventions. But it is having one more influence in robbing the telephone of its intimacy. After seeing a telephone play who would trust the instrument with any secret at all? What may thus be said of the drama can be said with redoubled energy of the Kinema. Watch the Kinema actress seize the telephone! Watch her as she brings it to her mouth! You can literally see her shouting into it. If ever there is a time when one rejoices at the silence of the Kinema it is when the telephone is in evidence. Indeed the telephone and its particular utility in disseminating sound has become the very warp and woof of the Kinema drama. And that is not the function of the telephone at all. It is the most secret of methods of communication. To-day between 10 a.m. and 11 a.m. there were some 20,000 conversations in Belfast They were intimate and secret The operators do not listen to them; they have something else to do, for the operator's work is so scientifically scheduled that she connects some 240 calls in the hour, and you will at once see that she has little chance of

listening, and if she had a chance the one thing she would have no taste for would be to listen. It is safer to speak on the telephone than to speak in a tramcar; it is safer to speak on the telephone than to write. Yet none of us really comprehend the fact.

I am assured that love-making on the telephone is only indulged by rare souls who have learned to trust the instrument. I heard a story some years ago of a man who was known by all the public (including the telephone staff) to be appallingly in love with his wife; it was in the earlier days. An operator found him speaking to his wife; the temptation was too great and she listened, alas! "And besides," he said, "I think I saw a cobweb over the middle of the sideboard. I'd sack her, if I were you." It was unpoetic; it cured the operator of listening. But if you want evidence on this heading come with me to the realm of fiction. English fiction makes a good deal of the love interest. Yet you never can find an instance of a love scene on the telephone. The young couple will speak by telephone, but it is a chastened and restrained conversation. I saw a novel last year which handled the situation in this somewhat crude fashion: "Molly!" "Yes, dear." "Did you get my letter?" "Yes, what a lovely letter!" "Which part did you like best?" "Oh, the last paragraph, it was lovely!" "Ill write again to-night." "Will you say it all over again?" "Yes, dear." "That will be lovely." Personally, I do not believe that such a conversation ever took place; I doubt if any self-respecting telephone would stand it. But it throws a light on telephone psychology. The writer of that novel was perfectly certain that on the telephone you could only hint at what you intended to say, and that the real declaration of one's inner feelings must be under a sealed cover. I shall come back to this aspect of the question later, but this timidity is all a part of the one fundamental characteristic of our use of the telephone—we have not realized that it annihilates distances—we have not realized its beautiful intimacy. Space is part of the framework of our minds, except

when dissolved by the faculty of sight. Some telephone philosophers think that we shall never be rid of the disability until seeing by telephone (so to speak) becomes an accomplished fact; just as we read in that ancient classic, the Book of Job, "I have heard of thee by the hearing of the ear, but now mine eye seeth thee." Something has been done in that direction, but not yet is it part of the interchange of communication, and I am afraid that it is not likely to be. We shall have to modify our telephone psychology without the aid of sight, and it will be a good discipline for us.

Much the same might be said as regards time. For some mysterious reasons, which I cannot explain, time is always erratic on the telephone. I have had respectable citizens, even ministers of religion, tell me in days gone by that the operator kept them waiting ten minutes. In one case it was a bishop, usually harmless, kindly disposed, and a lover of his kind. He had waited 35 seconds for an answer—too long, we admit, but his conception of the period was amazing. I tried him with my official stop watch, and I asked him to guess the length of certain periods of time both with the telephone in his hand and without the telephone. His guess was wonderfully accurate without the telephone, but with the telephone invariably he quadrupled the time once it got beyond ten seconds. Other citizens are affected in the other direction. They ask for a number; the operator picks up a peg and taps the terminal and finds the number engaged. She conveys the information to the caller. Of course she is quick; she is trained to be quick; we know to the decimal of a second how long it takes her to perform the operation. But I am constantly told that she never tries at all, that she just says "number engaged" out of spite or negligence. And this summary reflection on her honour is always based on the presumption that the interval of time is not sufficient. Now it may as well be said that with the telephone in one's hand the estimate of the lapse of small periods of time is invariably aberrant. Why it should be so I do not know, but I have tried my own estimate

again and again and have found it hopelessly wrong. Certainly I am not ready to condemn an operator merely on my own conception of the passage of time ; nor am I prepared to pit my conjecture of the passage of time against that of the various appliances given to the operator for making the record, appliances which both indicate the time and check the record. There are circumstances in which three minutes seems to be a desperately short period ; I expect the young man and maiden, to whose conversation I have already alluded, would think it had only lasted seconds when, in truth, it ran into tens of minutes. Other types of conversation seem to be prolonged. But the telephone machine is ruthless. Three minutes in its eyes are three single minutes. The operator who asks you to have another call has no interest whatever in cutting you short. She herself has her observers. She is doing her duty under the eyes of strict supervision. She is not knitting, even in days when all the rest of the world is knitting. She is not reading novelettes. She is not talking to her young man, that phantom young man of the subscriber's fancy, for to her the telephone is a professional thing, and even when all the rest of the world does its love-making by telephone she will scorn to do so. For to her it is unpoetic, her bread and butter, her craft. To the rest of the world it is an embroidery on life ; to her it is life itself. It has modified her conception of space and time in that it has made them real and accurate, the things-in-themselves. The rest of the world are only in process of having its conceptions modified. Psychologically she is in advance of her time.

There are other characteristics. It is strange how numbers are affected by the telephone. New limitations of memory are revealed. The transposition of digits follow broadly certain well-known laws. A subscriber will look at the directory and pick out a nmber, say 3547. This is a difficult number to remember in the brief period which elapses from the printed page to the telephone. Why? Because the human mind yearns to give the figures in sequence, and it *will* give them in sequence unless it is

watched. So that 3547 becomes 3457 in, as we may say, the twinkling of an eye. You will agree that there are certain numbers which will not stick in your memory. There are many instances where subscribers are frequently unable to remember their own numbers. The introduction of the "double" was a help. 3, double 5, 7 is an easy number to remember, for this reason. No doubt some of you have felt aggrieved when we introduced "O" (Oh!) instead of "0" (nought), yet we had a reason on our side. It is much easier to articulate "Oh" than "nought"; it is especially to be appreciated in respect of "double oh"; it is a clearer demarcation from 9. A telephone company in the middle West of America once proposed the substitution of "cinq" for "five," in order to avoid the old confusion between "9" and "5." That was an heroic suggestion. We have to get over it by teaching the staff the careful articulation of "five"—rather long—and "nine," crisp and sharp. You will notice, though it is not so striking in Belfast as elsewhere, because it is nearer the normal in speech, that our operators roll their r's, that they say "sev—en," that they pronounce the consonants clearly; of course they repeat back the figures, as a safeguard, rather differently from the way in which the subscriber has passed them. All this, you say, has nothing to do with psychology; it is a mere matter of articulation.

But it has a great deal to do with psychology. Do not forget that the telephone is a metallic instrument. It makes its speech by the vibration of a metallic diaphragm. Compare this to the beautiful flexibility of the human instrument and you will realise that the telephone is at a great disadvantage. Moreover there are some sounds which it is said the telephone does not carry at all, such as sibilants. Now here comes in psychology. The telephone auditor, in listening to the sounds which reach his ear has to build them up into the likeness of speech which reaches his ear direct and without the interposition of a metallic diaphragm. There are therefore two arts involved. There is the art of telephone speech, which has acquired by a process

largely subconscious the method of masking those sounds which are less efficiently carried by the metallic medium and of slightly emphasizing those sounds which are definitely and clearly carried by the medium. There is also the art of telephone hearing by which one learns to rely on the clearer consonants and to fit in the sounds which come less definitely. So it comes about that the person who hears most efficiently on the telephone is not the person whose hearing is most acute, but he who has reasonably good hearing and who also has the quasi-musical gift of building sounds into sound phrases, "out of three sounds he makes," as Browning says, "not a fourth sound but a star." Everyone is not equally successful with telephone speech, but it is true that far more persons are successful with telephone speech than with telephone hearing. Having said this by way of fundamental, I have to point out that there are further subtleties. In some extraordinary way not yet explicable there are certain sympathies which we have to take into account. Certain speakers appeal to certain hearers. Certain methods of articulation seem to suit certain psychological tendencies in piecing together the sounds which do come and the sounds which do not come. I have known cases where speakers whom I should expect to be perfectly clear on the telephone do not produce this effect at the distant end. Also I have known cases where men whose hearing is thought to be imperfect have shown astonishing skill in being able to interpret methods of articulation which do not suit the metallic medium of the telephone. The fact is that the telephone does not seem to us to be mechanical. We have forgotten that it can only apply the transmission of sounds to human use by means of a mechanical medium. There is a great religious leader who is said to be buried with a telephone in his coffin, readily joined up, to be used in emergencies. That was a profound compliment to the telephone. For that religious leader always asserted the purely spiritual nature of the resurrection, and in doing so he forgot that by installing a telephone he was insisting upon a mechanical means of transition.

But something more than the voice is carried. Mechanical though the instrument is yet it does convey a conception of character. There are some, though very few, well-authenticated cases of "falling in love," that emotional crisis of which psychologists have given so many and so varied explanations, over the telephone, without any personal or direct acquaintance. The New York Telephone Company tells its operators that the cultivation of a soft voice is a sure way to matrimony and points boldly to statistics which proves the thesis quite as readily as they prove anything else. But it is not the soft voice which alone, to use a colloquialism, "does the trick." There is some intangible method or inexplicable method of conveying the sense of character by telephone. The subscriber sometimes lays down his telephone, smiles benignly, and says "*That* is a real, nice girl." Of course she is. But why does he say so? He knows nothing of the colour of her hair, the poise of her head, the slow graceful carriage of her body, all so dear to the novelist who describes in his own way the motions of love. She has spoken courteously to him—perhaps to the extent of half-a-dozen words, and at once he makes up his mind that if the worst comes to the worst he will take her as a daughter-in-law. He sums up her character in a twinkling, without a shadow of doubt, not caring how she behaves to her brother, what her ideals are for the future government of the world, or how she could make a currant cake, in days, that is, when there were currants. I believe that the arrival of our young women as telephonists in France had a marked influence. Crusty generals adopted almost tender addresses; weather-beaten colonels found the telephone suddenly efficient; subalterns developed new chivalrous instincts. They could not help it, for courtesy and determination to help are infectious. Indeed I could go farther. The telephone reveals character in an amazing way. Ordinary interchange of speech often hides our motives. "We say unkind things in a kind way." But the telephone brings out the hidden springs. John Smith, whom you know as a decent citizen, cordial and reasonably kindly, is

known to be a brute on the telephone. Not that he changes his spots like the leopard, but that the telephone reveals the spots. There is something to be said, therefore, for the Cupid-blind method of making perfect marriages, not in Heaven, but by the telephone. Only those who do it must trust the telephone absolutely and, as I have shown, it is not easy. For the average man or woman amongst us the telephone will be an enemy to love-making. It will reveal that skeleton in the cupboard of our characters which, at any cost, must remain hidden. The telephone is the Mother Hubbard who goes to the cupboard and finds not merely a bone but the complete skeleton.

There is room yet for a vast amount of research on this subject. Not indeed that those of us who have spent years of our lives associated with telephone practice have ignored the subject. But for the true investigation the student will need a considerable knowledge of the mechanics of voice production and of the science of acoustics. Even so, he will be imperfectly equipped unless he has some acquaintance with the modern developments of psychology. For some of the margin of these studies belongs to psychology. You will readily understand now how strange errors occur in telephone speech. There have been instances where whole phrases have been imagined, to use the popular phrase. It is as if the sub-conscious mind, in building up the material which I have indicated, was sometimes urged forward to operate beyond its proper limits. And other senses come into play. I once knew a telephonist who, whenever she had the task of controlling a certain circuit, always declared that she could smell the chemicals, which were notably allowed to escape in the town at the other end. The remedy was simple. A telephonist who had never been in that town was altogether unaware of the smell. Indeed we have found that the active co-operation of the sub-conscious mind in telephone operating has produced the most curious results. It has not the check which vision places upon it, and in some temperaments has been rather inclined to lead to difficulties. But you must remember

that in saying this we are dealing with a twilight realm. The simple fact is that clear enunciation of consonants reduces this twilight realm to very small dimensions. The experienced auditor, using reasonable care, reduces the possibility of error to almost a negligible degree. In that division of the Head Post Office where telegrams are accepted by telephone—the most severe ordeal to which the telephone is subjected—there is a singularly small proportion of error. Of course we take special pains and it is a subject which is always being studied, but in the main it is true to say that the errors are no more numerous than in the case of telegraphs proper. And it has long been known that even in respect of telegraph symbols, clear and definite though they appear to be, psychological factors have their place in the accuracy of signalling and receiving.

The new science of experimental psychology is making big demands upon us to-day. Even vast wars are influenced by psychological means : the temperament of nations is regarded as a proper field for the operation of suggestion, and it looks as if the might of arms were within the influence of psychology to some extent which we cannot estimate. From great things we come to small, and I claim that if we are to use the telephone efficiently we cannot despise the close study of these psychological factors. If we kept some sort of open mind on the subject, some sort of tolerant expectation of more light, we should be less prone, at times, to lose our tempers and less prone to blame a body of women who are rendering the public really faithful and zealous service. For the greatest beauty of the telephone lies in the fact that it makes a corporate demand. The best telephone in the world cannot give an efficient service to the man who does not speak clearly to the middle of the diaphragm and does not strive to gather together all the elements of sound which go to make up the speech which is destined for him. The psychology of the telephone is the psychology of mutual dependence. It affects us far more than we suppose. It modifies our speech ; it quickens and enlightens our hearing ; it sharpens that sub-conscious mind

which works ever on our behalf. It shows us that evidence which we take to be certain is not always positive ; it warns us that sometimes we err in that unconsciously we have made a a mental contribution to contributory facts as they seem objectively to be. It is a check against over-confidence, a guide-post against assertiveness, a builder of character in that we learn the lowliness of the human unit and his dependence upon factors the existence of which he has scorned. Thus I claim for telephony a creditable position in the world of psychological practice- Not yet has it come into its own. Only for some 30 years has it affected on any considerable plane our day-by-day lives. But when the day comes, as come it may soon, for the telephone to be extended so as to fulfil more nearly its proper function, we shall realise how great has been its kingdom over the human mind, for in that day the kingdom of the human mind will have its true place among the realms of earth, its true dignity in the league of nations.

9th April, 1918.

DISCONTINUITY IN THE PHENOMENA OF RADIATION.

By Mr. James Rice, M.A.

The idea of continuity has been of supreme importance in the development of all departments of Science. Let us be clear at the outset as to what this idea implies. It certainly does not preclude the possibility of *sudden* changes, i.e., changes in the properties of bodies taking place at rates which are to be regarded as very much greater than the normal values for such rates. To take a simple example, the impact of two billiard balls offers an illustration of the fact that a change may be sudden without being discontinuous ; for we have no reason to suppose that the laws of motion, to which the balls are subject at the other periods of their motion, are inoperative during the brief interval when they are in contact and their surfaces are being progressively strained from their normal shapes and restored to it. A discontinuity in a natural occurrence implies the existence of a period of time, long or short, in which laws, previously assumed to be of a general character, are found to fail and cease to explain the occurrence in a manner consistent with established principles.

It is in the realm of Biology that the notion of continuity has made its most signal contribution to the advaucement of science. The assumption of the evolutionary growth of all living forms from protoplasm without the intervention of "special creations" is the most striking example of the application of the principle of continuity to which one can direct the attention of a general audience. Yet even in this department of science phenomena in which discontinuities appear to be present have been plentiful ; so much so that the particular theory of variation of species which is associated with the name of Darwin has had to

be modified and extended in the constant endeavour to obtain a principle wide enough to bridge the gaps which constantly come into view with our increasing knowledge.

The part which continuity has played in the development of Mathematics and Physics is not so well known, but students of those subjects can bear testimony to the fact that without it their present position would not have been attained The calculus is the very embodiment of mathematical continuity, and it is in the realm of the so-called "continuous functions" that it has given the most striking examples of its power. The belief that all physical and chemical phenomena are but continuous transformations of energy from one form to another, which could ultimately be explained by the laws of Dynamics, has had a profound effect on the minds of all physicists and chemists. But the struggle between discontinuity and continuity is making itself felt here in a manner too marked to ignore. The desire to found his subject on a vigorous and unassailable basis has of late driven the mathematician from those elegant applications and developments of mathematical analysis with which all mathematical students are so familiar, to the close and careful scrutiny of his methods and assumptions and the thorough study of those discontinuities and singularities in mathematical functions which his predecessors used to pass by with airy indifference. In Physics we are faced with difficulties of a like nature. By reason of the refinements of modern experimental methods older theories of radiation and the heat content of bodies have been found wanting. Where we previously pictured an output of energy in a continuous and orderly fashion, we have now apparently to postulate something of a catastrophic nature, a discontinuous emission of energy, whose essentially disturbing feature is not so much its suddenness, as our inability to fit it into the scheme of laws and equations which have hitherto served to summarise our knowledge in this branch of science. The solution of this difficulty will, it is expected, provide us with the key to several other difficulties still preventing an advance in this subject.

It is to this particular difficulty that I wish to direct your attention this evening, and to make the matter as intelligible as possible to the non-physicists among you, I must recapitulate certain facts and definitions; and in this recapitulation the exigencies of time prevent me paying too much attention to the historical and logical order of the development of the ideas presented.

The nineteenth century witnessed the foundation of the energy principle. In a limited form conservation of energy may be said to date back to Galileo, and Newton made a clear statement of it for a restricted range of phenomena; but it is on the work of Carnot, Joule, Clausius, Rankine, Thomson and Helmholtz that its acceptance in the widest sense reposes to-day. That form of energy which we most readily apprehend is the energy of moving matter—so-called kinetic energy—and the mathematical physicist demonstrates for us how it is to be measured, viz., by multiplying half the mass of the body by the square of the velocity, and, if need be, by certain numerical factors also, according to the particular units in which we desire to express the result—ergs, joules, foot-pounds, etc. Another form of energy possessed by matter is that known as energy of position or energy of configuration. A body possesses this by reason of its occupying a position of advantage with respect to other matter in the universe which is exerting force on it, or by reason of the fact that it is strained from what may be called its natural shape or configuration. Such energy is generally referred to as "potential"; for if the body leaves its position of advantage or returns towards its natural shape it does so with increasing movement, i.e., with gradual increase of kinetic energy, so that this acquired energy of motion may be said to be latent or potential in the matter as it was originally situated or strained. The important feature about the possession of this type of energy is that it depends upon the action on the body, by other matter, of forces which arise solely from the position of the body or from elastic stresses set up in the body by its deformation—forces and

stresses which are quite independent of the body's state of motion, and which exist whether it is at rest at or in motion through the position or configuration considered. Once more the mathematician teaches us how to measure the amount of potential energy which a body in one position possesses in excess of what it possesses in another, viz., by the mechanical work of the forces as the body passes from the first—and more advantageous—position to the second—and less advantageous—position. The formulae obtained vary with the nature of the forces involved and the particular laws which connect the magnitude of the forces with the relative position of the body. In one very important case, the energy of a raised mass, the measure is obtained by multiplying the weight by the height, and perhaps by a numerical factor suitable to a special unit of energy. In another case, the energy of a stretched string, the result depends on the tension and the elongation of the string—half their product giving the energy of strain.

It used to be urged against the workings of the scientific mind that it sought to give a "mechanical" explanation to the universe and to life itself—the implication being that in so doing it affected to regard living matter as a "dead machine," an automaton without emotions or feelings. The implication was, of course, false, but the original statement contained an element of truth in so far as there has always been on the part of the scientist an effort to explain all *physical* and *chemical* changes in terms of movement of matter, especially matter in the molecular, atomic or subatomic form; such movement being always subject to the dynamical laws, which were first propounded clearly by Newton, and whose consequences were fully worked out by the great mathematicians of the 18th and early 19th century. One of the deductions from these laws establishes the existence of an exact equivalence between the two forms of energy just dealt with, whenever the forces involved are of a *conservative* nature—in practice this would exclude the action of forces arising from friction and percussion. Whenever the

body loses energy of motion under these restricted conditions, it gains energy of position and *vice-versâ*, or at all events this conservation can be demonstrated for a system of bodies which, while mutually acting and reacting on one another, are freed from external influence. For many years, the view that heat was a material substance, barred the natural extension of this deduction to the view which regards the molecules and atoms of a body as a system of bodies, themselves subject to dynamical laws, and consequently brings their relative motions and positions within the scope of the energy principle. With the gradual abandonment of the belief in the material nature of heat, came the conviction that heat was but the energy of molecular agitation. This, at all events, was a tenable and highly plausible hypothesis, and permitted a great extension of the energy principle on the assumption that all intermolecular forces, such as cohesion and those developed during friction or impact were subject to Newton's laws. That was the state of affairs when in 1840 Joule began his famous experiments on the equivalence between heat developed by friction and the mechanical work expended in maintaining the motion of the rubbing bodies. The positive results of Joule's work and that of his successors constitute one of the finest achievements of the 19th century. After that first step other developments followed rapidly. Not only can matter in its molecular and atomic form possess energy of motion; it can also possess potential energy. Energy of strain becomes resolved into the mutual energy of position of the individual molecules separated as they are from one another in their vibrational movement against their mutual attractions. The absorption by a liquid of latent heat as it is converted into vapour is but the conversion of kinetic energy of the molecules of the fluid into potential energy as those molecules escape from the liquid, and not only rise against gravity but also separate considerably from one another against the mutual attractions which hold them together in the condensed form. The electric energy of the materials of a voltaic cell, the chemical energies of various

substances which enter into combination with one another are also examples of molecular potential energy, and all are capable of being converted into molecular kinetic energy—it is this conversion we are dealing with when we speak of heat of reaction, combination, combustion, and so on. Indeed we measure such energies by the amounts of heat procurable by their conversion under well-defined conditions. The work of Joule and his followers has given us, as it were, a currency in which we can measure any amount of energy and in any form, just as in the world of economics we measure the value of all commodities in terms of one commodity—money. All forms of energy are ultimately measurable in terms of heat energy, although in actual experience we may measure an amount of energy in terms of an energy which is not thermal but one whose value in thermal units is known.

We have by no means exhausted all our stores of energy in the short statement just made. Energy, for instance, reaches us from the sun in a form whose importance is manifest to all. It is established beyond doubt that it requires some time to reach us—about 8 minutes in fact. It is decidedly inconvenient for us to conceive a quantity of energy leaving the sun at an instant and turning up on the earth's surface 8 minutes later, if we cannot make it give some account of itself in the meanwhile. We absolutely refuse to believe that it is non-existent in the interim. There is no material substance in the intervening space to attach it to; so we invent one, put the energy into it, and call it radiant energy. A very arbitrary act, no doubt, and many scientists, even the great Newton himself, had serious doubts about it. Yet the "proof of pudding, etc." Its justification lies in the coordination of our knowledge thereby effected, a coordination whose completeness can only be appreciated by those engaged in the study of physical science.

To the physicist, indeed, it is not a question of the existence of the ethereal medium; his difficulty lies in its nature; his doubts are centred around the properties he is to ascribe to it.

For many years some of the best brains in Europe struggled to show that there was, for instance, no essential difference between the transmission of a beam of light through the ether, the transmission of an earthquake shock through the earth, and the transmission of a wave through water. But it was just on the nice combination in the ether of the property of rigidity possessed by an elastic solid like the earth with the property of fluidity possessed by water, that full success was wanting. There came a second phase when Clarke Maxwell, abandoning attempts to explain the physical properties of the ether in terms of those of matter, essentially reversed the problem, and began the modern attempt to found an electrical theory of matter by pointing out the similarity of light waves to the electrical waves with which we girdle the earth to-day—although Maxwell himself did not live to see his prediction of the existence of these waves actually verified. Tremendous success followed on this suggestion; it proved a landmark in the history of Physics; but like all great advances, it brought its own difficulties, and those difficulties have accumulated until to-day it would appear that we are awaiting the advent of another genius, a Newton or a Maxwell, to usher us into a third phase. The trouble is, to put the matter in a crude way, that the ether, so far from being a substance whose existence is in doubt, has acquired such enormous importance that we are hard put to it to explain why it does not possess all the energy in the universe, and why matter, as we appreciate it by our senses, possesses any at all and is not in reality the dead and inert thing so scorned by a former generation of anti scientific speculators.

To appreciate the nature of the present impasse, I must ask you to follow me into some considerations of a rather special nature, concerned with the manner in which the physicist measures radiant energy and in what particulars he distinguishes one quality of radiation from another. To be sure, in the eye one has an instrument in some slight degree suitable for that purpose—but one too crude and too limited in its range to be of

much scientific value. For one thing, the eye is quite incapable of distinguishing between two radiations producing the same colour sensation, which a modern spectrometer will resolve with the greatest ease; for another, as is well known, the particular qualities of radiant energy which are capable of affecting the retina constitute a very narrow range of the totality of ethereal vibrations.

We can probably approach the question in hand by considering a wave motion in a medium where we can follow the occurrences with great ease. Picture a small needle with its point just touching the surface of a pool of water, and compelled by some mechanism to oscillate up and down; a disturbance is created in the water, and alternate crests and troughs travel out with a definite speed from the centre of disturbance. There are obviously three quantities of immediate importance; one is the frequency of oscillation of the needle or disturbing mechanism, i.e., the number of vibrations executed per second; the second is the wave length of the train of waves sent out—that is, the distance from crest to crest, or trough to trough, or, in general, between two successive rings of water in the same phase of motion; the third is the speed at which the rings travel out. Of course, when we speak of the rings travelling out, we are referring to an outward movement, not of the water itself, but of a particular form or configuration of the water. As far as the water is concerned, each drop of it is rising and falling like the needle point, and with the same frequency. Very little experimenting is needed to prove to us that the more frequent the oscillations of the needle the shorter is the wave-length of the ripples. Indeed, a little thought shows that the two are very simply connected, that in fact the wave-length is the distance which the disturbance advances outwards while the needle executes one complete up and down oscillation, so that the wave-length is determined by a division of the speed of the ripple movement by the frequency of the needle's oscillation. It is clear that for such simple and almost ideal wave motions as these

one important distinguishing factor is wave-length, or its equivalent, frequency. Another feature is the amplitude of the oscillation of the wave particles, i.e., the extent of movement between the highest and lowest point. This diminishes, no doubt, as we recede from the needle, but at any one defined spot it depends on the amplitude of movement of the needle, and may be increased or decreased by variation of the extent of the needle's oscillation. So we naturally discriminate between two ripple-trains by the details—wave length (or frequency) and amplitude. The water is, morever, the receptacle of energy which is being imparted to it by the vibrating mechanism of the needle, and which we readily apprehend as existing in one of the two most familiar forms, kinetic energy or potential energy. At places where the water is momentarily at its undisturbed level, the energy is entirely that of motion ; for there each particle is passing through its mean position, upward or downward, with its greatest speed. At the trough or crest the energy of each particle is for the instant all potential, since in the former case the pressure of the surrounding elevated water gives an excess of upward force which will presently impart kinetic energy to the drop against downward-acting gravity, while at the crest the conditions are reversed, but with the same result—possession of potential energy. At other phases of motion the energy is partly kinetic and partly potential. But whatever the form it takes, the existence of an energy in the water, which has been "emitted" by the mechanism controlling the needle, is obvious.

I have chosen this very simple and commonplace example of wave-motion, because its very simplicity exhibits all the essentials for a general grasp of radiation problems ; it is, in fact, a case of actual radiation in the wide sense in which that word is used to-day. Allow me to make a little further use of it, in order to show you how physicists measure the wave-lengths of those ethereal vibrations which possess the simple qualities which we have attributed to the ripples. In the case of the ripples themselves the measurement of the wave-length would appear to be a

simple matter of a ruler. It is nothing so easy. I should not envy the man who essayed to measure the wave-length of a train of moving ripples to an accuracy of, say, one per cent., with nothing but a foot-rule for apparatus. And yet the measurement has in it simplifying elements absent from the corresponding problem for light waves. The medium, water, appeals directly to our senses; its oscillations, which are of course not merely surface phenomena, are all the more easily observed by the fact that there is a surface whose changes of form disclose to us the underlying movements. Further, even in the case of the tiniest ripples, the wave-lengths are enormous compared with those of light. However, if you look at this slide*, it may help you to obtain a sufficient idea of the means adopted by the physicist for attacking this problem. This picture is an instantaneous photograph of the surface of a shallow dish of water which is being disturbed by the oscillations of two needles, both vibrating with equal periods, and each one exciting a ring-shaped train of ripples whose wave lengths are equal. The apparatus employed in the production of this picture is called a ripple-tank, and requires the nicest adjustment between the mechanism actuating the needles, which is an electrically driven tuning fork, and the photographic apparatus, which is in reality a scientific adaptation of the cinematograph camera. The picture shows you an instantaneous view of the surface of the water. What you observe is that along a series of radial lines or channels, diverging from a spot between the needles, the water is absolutely undisturbed, while along the intervening radial channels you have the water surface corrugated in crests and troughs, The photograph shows you that as a matter of fact along certain paths there is no energy of vibration transmitted at all; the two wave-trains are said to interfere along such lines. Along the intervening paths the wave-trains reinforce one another, and all the energy emitted by the vibrating mechanism is directed along these channels. The reason for this

* Fig. 1.

FIG. 1.

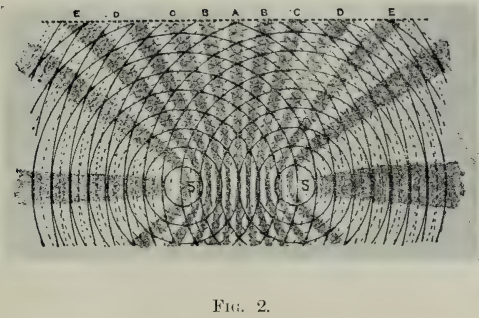
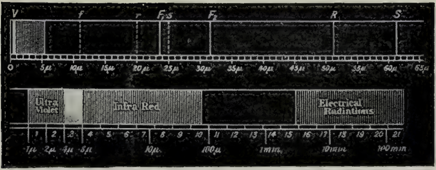


FIG. 2.



Range through which Ether Waves have been investigated.

FIG. 3.

state of affairs may be gathered from the next slide*, which presents to you a diagram illustrating by thick and dotted lines the crests and troughs of each wave-train as they would be situated at a definite moment, were the other train absent. Where crest cuts crest, or trough cuts trough you would expect reinforced oscillation, and you will notice that such intersections do actually lie on radial lines; while where crest cuts trough you would expect interference and absence of energy flow, and such intersections, once more, lie on radial lines, which separate the previous set of lines. Furthermore, you will experience no difficulty, I presume, in appreciating the fact that if the frequency of the oscillation of the needles were increased the channels of energy flow would be more numerous and more closely packed; their angular separation would be less, for with increased frequency the common wave length of each train would be decreased, the thick and dotted circles of the second slide would be more numerous, and the lines of intersections, therefore, more numerous as well. Indeed, there is a very simple relation which connects the wave-length of each ripple-train with the separation of the lines of energy flow when the distance separating the needles is known, and by its aid wave-length could be calculated if other and more direct methods were not available. One limiting condition must be observed before we leave this illustration; the frequency of the oscillation must neither be so great nor so small as to make the wave-length too small a fraction or too great a multiple of the distance apart of the needles. In the first case the channels of flow would be so numerous and closely packed as practically to obliterate the intervening quiescent avenues, while in the second they might not exist at all.

In applying this method to the problem of light radiation, we naturally ask are there sources of light which send out ethereal vibrations of such a simple character as that possessed by our ripples, having the necessary uniformity of wave-length

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* Fig. 2.

along the whole train; and also can we obtain two or more sources of such light as nicely adjusted in phase to one another as the needles of a ripple-tank. The answer is in the affirmative. The light emitted from incandescent sodium, lithium, strontium, to choose a few familiar substances, the light emitted from tubes containing traces of any gas and electrically excited by a coil possesses in a high degree those elements of simplicity required. From such sources we can obtain beams of almost homogeneous or "monochromatic" light, i.e., light of definite wave length or frequency. Square across the path of such a beam we can put what is called a grating, consisting of a series of fine, equally spaced, parallel lines ruled by a diamond point on a piece of glass. Such lines serve to scatter and absorb some of the luminous energy of the advancing beam; the remainder of the energy will emerge through the clear pieces of glass between the lines—the spaces as they are called. These spaces, as a matter of fact, serve as sources of light possessing that nice adjustment of phase which was postulated above as an experimental necessity. Instead of two such sources only, we generally have several thousands. The essentials of the occurrence are, however, still preserved; it is found that the light energy is directed not merely along its original direction, but also along several other well defined directions. The slide shows you a crude picture of some of the energy being directed along one direction; it is collected by the lens and focussed to a fine line. The slide shows you only one of these lines corresponding to one direction of energy flow. There are in general several such line images, and their distance apart serves to determine the angular separation of the various paths of the energy, and this, as you will remember, determines the wave length. once we know the distance apart of the successive spaces of the grating. In actual practice the line image is projected on the vertical cross wire in a telescope eye-piece, which permits of a very fine adjustment of the telescope and a very precise determination of the divergence of each energy stream from the original direction of the light. As

already indicated in the ripple-tank photograph the wave length of the light must be comparable with the distance separating the successive spaces of the grating for the experiment to succeed. Fourtnately the skill of such physicists as the late Professor Rowland, of Baltimore, has placed at our disposal gratings with as many as 14,000 lines to the inch, and also photographic copies of these. Such fineness of ruling is absolutely necessary for accurate work on light. The wave length of any homogeneous light is so small compared with our usual standards of measurement that we find it convenient to introduce two new units of length into use, viz., the millionth part of a metre, i.e., the thousandth of a millimetre, which is called a micron, and the thousandth part of this length called a millimicron. Rowland's gratings have their spaces separated by distances of the order 2 to 3 microns, the separation being known from the mechanical means by which the ruling was carried out. The results of measurements with such gratings and other apparatus designed for similar purposes is to prove that when we analyse the white light of the sun or electric arc into a spectrum band on a screen by prism or grating the light which illuminates the extreme red end of the band has a wave-length of ·8 micron approximately, while the light illuminating the other, the violet, end is about ·4 micron in wave length. To indicate the precision of measurement possible in spectrometric work, it is known that the yellow light emitted from incandescent sodium vapour is composed of two homogeneous qualities, one having a wave length ·5890 micron and the other ·5896 micron, a difference in wave length of but ·6 millimicron. This excessive shortness of wave length carries with it as its natural counterpart an extreme rapidity of vibration on the part of the mechanism inside the atoms of the radiating, luminous material, and also on the part of the ethereal medium through which the light is transmitted. These frequencies can be calculated very easily from the known speed of light through the ether, which is 300 millions of metres per second. For extreme violet light it turns out to be about

750 billions of vibrations per second, and for extreme red light about half of this number. (Billion is taken to mean 10^{12} or one million millions).

We are able to do more than measure the wave-length of a stream of radiation ; we can also measure the amount of energy which is carried per second across any section of its path. To do this the cross-wire of the telescope in the spectrometer is replaced by an extremely thin strip of some metal coated with a highly absorbent material such as lamp black. The energy of the concentrated stream from the grating is converted into the universal currency for measuring energy, viz., heat, in the strip. The strip itself forms part of an extremely sensitive mechanism in which an electric current is generated by the heat thus developed, this current being measurable by a delicate mirror galvanometer. The sensitiveness of such "radiomicrometers" is such that a rise of one millionth of a degree in the temperature of the strip is observable with accuracy.

The possibility of using such radiomicrometers is of extreme importance ; for, as is well known, there exist radiations which do not affect the retina. Our only direct experience of them is the sensation of glow when we stand before a fire or hold our hand near a hot kettle, etc. Such radiations are poured forth in profusion from all bodies, hot or cold ; only at the extreme zero of temperature, the so-called absolute zero, would any body cease to radiate. This fact generally eludes us because of our lack of direct sensation in many cases, although we occasionally experience one result of it, viz., the chilly sensation near a very cold body, arising from the condition that we are radiating more to that body than it is radiating in return to us, involving a net loss of energy on our part. At all events their existence is undoubted. They can be directed from bodies, luminous or not, to a grating ; the diffracted streams from the grating can be detected by means of a radiomicrometer, and measured both as regards wave-length and intensity. The photographic plate is also an extremely useful appliance in radiometric work ; the camera can replace the

telescope of the ordinary spectrometer, and the position of the dark lines and bands on the developed plate give the necessary data for measuring the direction of the diffracted streams of radiation which produced this effect on the negative. The amount of chemical action at each line on the negative, estimated by the depth of tone, indicates the intensity of the stream of radiation. With the specially sensitized plates available to-day, the range of radiation over which the photographic plate can be used is very wide, but it is for those qualities of radiation which are shorter in wave-length than the extreme violet of the visible spectrum, the so-called actinic, photographic or ultra-violet rays, that it has been mainly employed.

My remarks so far have been based more or less on the assumption that ideal radiations of precise and definite wave-length exist and are detactable. I must qualify that statement somewhat. As already stated, there are certain luminous bodies, such as the incandescent alkali earths, or electrically excited gases, which emit radiations approximating to the ideal form; but even in such cases, what we actually detect is a stream of radiation with wave-length between certain limits, restricted, no doubt, but still not absolutely identical. The reason for this is not merely the finite dimensions of our receiving and detecting apparatus; it lies in the very nature of matter itself. But apart from such radiations as are approximately monochromatic or homogeneous, we have in the sun, the flame of a candle, the incandescent metal filament or mantle, the electric arc, and so on a whole series of bodies which are pouring forth radiations which are the very opposite of homogeneous. Even the tumbled surface of a choppy sea can only give an imperfect analogy to the complexity of ethereal vibration which must be set up by the presence of an ordinary incandescent solid. Yet the grating and radiometer can evolve order out of that seeming chaos and discover uniformity of behaviour. The grating will analyse a stream of such heterogeneous radiation into component streams, each stream having its own narrow limits of wave-length or frequency, and

each producing on the radiometer (if set in the correct position to receive it) an effect denoting the intensity in which it existed in the original heterogeneous stream. We can say that these quasi-heterogeneous streams existed in the original one, just in the same sense that we say that the violet, blue, green, yellow and red of the spectrum existed in the original beam of sunlight before it was analysed by prism or grating. By these means physicists have actually been able to isolate from radiant energy emitted by various light sources, radiations extending as far into the ultra-violet as ·06 micron, and as far into the infra-red as 300 microns, or ·3 millimetre, which correspond to limits of frequency of about 5,000 billions per sec. and 1 billion per sec respectively. It will be, of course, readily grasped that the dimensions of the gratings used for such extremes must be varied with the qualities measured; for the spacing of the grating must always bear a close relation to the wave-length measured.

This range of wave-length by no means completes the picture—far from it. The absorbing powers which the materials of our apparatus possess for all qualities of radiation, and for some qualities in a very high degree, prevent us at present extending research in the immediate neighbourhood of the limits mentioned. But that radiations of longer and shorter wave length exist there is absolutely no doubt. The ethereal waves of wireless telegraphy are extreme examples of long wave-length. The huge antennae employed to-day emit radiations whose wave-lengths attain in some cases to 3 kilometres, corresponding to a frequency as low as 100,000 per sec. When Hertz first isolated electrical waves in 1887 and verified Maxwell's prediction, he worked with waves about 60 cms. long, small enough compared with those that flash our messages across the oceans, but enormously long compared even with the longest of the so-called infra-red waves detected from ordinary sources of light. But just as some workers, by increasing the size of the emitting apparatus, have produced electrical waves of great wave-length for purposes of communication, others by diminishing the size have sought to

bridge the gap that separates the early Hertzian waves from the long infra-red waves and have so far succeeded as to reach a wave-length of 6 mms. The accompanying slide* will give you some idea of radiations which have actually been detected and measured by the variety of means at our disposal, except that the dark portion indicating the gap between infra-red and electrical should be actually smaller owing to work carried out since this diagram was constructed. Further, a remarkable series of researches carried out since 1912 have suddenly opened up a new field of knowledge at the other extreme of the complete radiation range. This refers to the nature of the X-rays. It had long been suspected that they were ethereal vibrations with the same elements of undulatory motion in them as in ordinary light waves; it was also known that if this view as to their nature were correct, their wave-lengths must be very short compared even with the 60 millimicrons or ·06 micron of the extreme ultra-violet so far attained. This inference has been fully justified. Taking up an observation, first announced by Professor Laue of Zurich, Professor Bragg of London and his son, together with the late Henry Moseley of Manchester University, published a series of researches opening up a new avenue of knowledge whose possibilities we are just beginning to realize. Sufficient to say, that they have demonstrated beyond doubt the ethereal nature of the X-rays. From the heterogeneous stream of X-ray radiation emitted by any bulb, it is possible to isolate and measure the wave-lengths of individual, almost homegeneous, streams. It is possible also, by varying the metal of the anticathode and by using a high enough voltage, to make a bulb emit practically nothing but an extremely homogeneous radiation, characteristic of the particular metal used and closely analogous to the kind of radiation emitted, say, by incandescent sodium except for the much shorter wave-length. The natural unit of length for these waves turns out to be the millimicron, or even ·1 of it, the so-called Angstrom unit. Thus, for instance,

* Fig. 3.

anticathodes of the heavy metals, such as platinum, palladium, rhodium, tungsten can be made to emit radiations with wave-lengths equal to about half of an Angstrom unit, or ·05 millimicron. Lighter metals radiate with wave-lengths somewhat longer, for example about ·15 millimicron for copper.

Before leaving this explanatory portion of my lecture, I ought to mention that we cannot escape the conclusion that those oscillations which we can excite in material bodies by hammering, bending, etc., and which give rise to aerial vibrations producing the sensation of sound, also give rise to ethereal vibrations, which, however, would be in the main of excessive wave-length and of the feeblest intensity. Also all that oscillatory motion in the molecules which we call the heat-motion must give rise to ethereal vibrations, even when the body is not luminous ; in fact such vibrations do constitute some part of the infra-red vibrations. The shortest qualities of the infra-red, however, together with the luminous ultra-violet waves originate from mechanisms within the atom, no doubt the rings of electrons, constituting the " planets " of the " solar system " to which now-a-days we liken the structure of the atom. In X-rays we are doubtless receiving intimations of violent changes going on in the very interior of the atom itself, its innermost rings of electrons, perhaps even in its very nucleus, that positively electrified core which seems to hold the negative electrons in their orbits against centrifugal action and mutual repulsion.

What picture does all this give us of the condition of the ether with which we have had perforce to fill our universe. One whose very complexity it seems hopeless to analyse, compared to which the most violently agitated water surface seems simplicity itself. Yet that hopelessness is not justified. In the grating and radiometer we have means of analysis which have brought us considerable knowledge, and the past history of science fully supports the view that out of all the seeming disorder the mind of man will evolve order. Indeed he has already made a good start, but one serious difficulty confronts him.

Let us return to the analogy of the water surface. Suppose our pool or tank of water has not merely one or two needles touching it, but millions. Conceive each one to be oscillating up and down as before, with all varieties of frequency and form of vibration, The surface of the water will present at any instant a form which must be the synthesis of all the individual movements which would exist alone were all needles but one at rest. In the same sense as we say that there are red, green and blue in the white sunlight, so we can say that there are in the complex motion of the water surface all the individual wave motions emitted by each needle, and a natural question presents itself—can we from the actual wave surface determine the wave length and intensity of each individual train? Well that problem certainly meets too many mathematical obstacles to be soluble in any but a few limited cases. But another consideration equally interesting crops up. Supposing we have some knowledge of the movement of the needles, not necessarily a detailed one, but something about their average behaviour, should we not then be able to infer something about the resultant movement of the water surface, again not detailed knowledge necessarily, but behaviour on the average? Now turn from this two-dimensional picture: think of the three-dimensional ether aud the analogues of our needle-points, viz., the molecules, atoms and electrons of matter, all in excessively rapid movement in it and all exciting ethereal radiations whose frequencies and intensities are dependent on these movements. To narrow down our problem to quite manageable dimensions, let us abstract ourselves from open space where we meet with bodies with all varieties of temperature. This is a perfectly legitimate procedure in investigating the elements of a problem. Let us think of this room—with ourselves removed from it, as causing too much disturbance—having walls, ceiling, floor, etc., all at one temperature, and quite impervious to all radiation from external sources; whether we leave the air in it or not does not matter. The enclosed ether is excited by radiations proceeding in all directions, emitted by the

walls, each train, as it reaches the wall again, being in part reflected and in part absorbed only to be emitted once more. No we do know something about the molecular movements in a piece of matter at a given temperature, not detailed knowledge concerning any individual molecule to be sure, but knowledge concerning average behaviour. From that knowledge we *can* infer certain results concerning the movement of the ether in our "constant temperature enclosure" Furthermore, it is possible to test these inferences, and unfortunately while some of them are verified, one very important one is absolutely at variance with the facts.

To show you where the contradiction arises, I must necessarily try to explain to you what is the kind of knowledge we have about molecular and atomic motion. To do so, I take the simplest instance possible, molecular motion in a body of gas, where the molecules spend the greater part of time practically free from each other's influence or that of the molecules in the sides of the enclosing vessel. The whole theory of such molecular motion has been very thoroughly worked out and can be found in books on the Dynamical Theory of Gases; the results obtained are numerous and in many cases capable of verification; in fact few single bodies of scientific knowledge can show such a strong chain of influence and verification. One of these results refers to the average energy possessed by any individual molecule of the gas when its temperature is definite. At any instant among the enormous numbers of molecules present—and you must remember we are dealing with numbers of the order 30 trillions per cubic centimetre for a gas at atmospheric pressure—as many are travelling within any well-defined limits of direction as within any other similarly defined limits. Otherwise we would be having the gas pressing in one direction more than another. That is, there are no privileged directions of motion. At a given temperature there is one privileged speed; i.e., there are more molecules with speeds varying by not more than say 1 metre per second from this speed than there are molecules

varying by the same amount from any other speed. In fact more than 60 per cent. of the molecules have at a given instant speeds between one-half and twice this speed, and less than 1 per cent have velocities more than two and a half times it. For air in normal conditions it is about 460 metres per sec. Of course any one definite molecule will probably assume in its career the most various speeds, but the actual number within defined limits of velocity remains practically unchanged. Further the average kinetic energy of a molecule, that is the total kinetic energy divided by the number of molecules is a definite quantity, which depends on the temperature in a very simple way ; it is simply proportional to the temperature, provided we measure this not from the arbitrary zeros of the usual scales but from the absolute zero. Of course this average kinetic energy per molecule is a very small amount of energy indeed, even at very high temperatures, on account of the excessively small mass of the molecule. It can be obtained by multiplying the absolute temperature of the gas by a fractional number which is nearly 200 trillionths (i.e., 2×10^{-16}), the units of energy being those suitable to the C.G.S. system, viz., ergs. To avoid repeating this extremely small number too much let us indicate it by a letter, say a, and refer to the average molecular kinetic energy of a gas at temperature T on the absolute scale as

$$a \, \mathsf{T} \text{ ergs.}$$

The application of the same mathematical methods which have proved so successful in the case of gases, to the case of solid bodies is naturally attended with more difficulty, and the positive results are much fewer. As regards the energy of each molecule, however, a result, which is an extension of that for the gas, can be obtained with a considerable weight of evidence in its favour on the basis of ordinary dynamics. It is known as the Theorem of the Equipartition of Energy. Returning to the case of the gas for a moment, the mathematical analysis only considers the energy possessed by the molecule by reason of its general translatory motion, with no reference whatever to any internal energy

which the molecule may possess by reason of the relative motion of its parts to each other, i.e., its atoms, or even the electrons within the atoms. Considered in that restricted light the molecule has, as we say, three degrees of freedom, i.e., the most general *translatory* movement can be compounded of three partial movements in three defined directions, say, back to front, side to side, and up and down ; this is a natural sort of division in view of the three dimensional nature of our space. We also say that for each degree of freedom the molecule possesses an amount of energy

$$\frac{1}{3} a \mathrm{T} \text{ ergs}$$

giving the total, $a \mathrm{T}$ ergs, as before for the three degrees of freedom.

Now, when we go inside the molecule, as it were, we perceive the existence of other degrees of freedom. To a huge celestial intelligent being our solar system would be as one body travelling through space with apparently three degrees of freedom. To us, however, it appears as a number of discrete bodies with many degrees of freedom quite independent of its own present motion towards the costellation Hercules. Similarly the complexity of the structure of the molecule yields many more degrees of freedom than the three referred to, and the accompanying movements and vibrations must involve the possession of kinetic energy over and above the energy of translation. The theorem of Equipartition states that *in so far as such movements can be affected by conditions which alter temperature*, the molecule, on the average, should possess $\frac{1}{3} a \mathrm{T}$ ergs of kinetic energy for each such degree of freedom. I have put in a provisional clause, you will observe. On the grounds of pure Dynamics it should not be necessary to insert it ; the movements in question should be affected by changes of temperature. But that is the trouble, as we shall see. This enumeration of the average energy of the molecule is not exhaustive ; it refers solely

to kinetic energy. The very existence of these intermolecular vibrations of necessity postulates the existence of mutually restraining forces on the various parts of the molecule, and such forces involve the possession by the molecule of a certain amount of internal potential energy. Further, if the molecule constitutes part of a solid body there will be restraining forces of cohesion on the molecule as a whole involving possession of still more potential energy. Under certain rather restrictive conditions, but, nevertheless, conditions which are of considerable importance in practice, we can say that each molecule, in addition to the total kinetic energy referred to, possesses on the average an amount

$$\frac{1}{3}\, a \, \mathsf{T} \text{ ergs}$$

of potential energy for each degree of freedom of motion which involves *vibratory* movement. I must ask you to bear in mind the fact that these are statements about *average* values of energy. They are entirely statistical. The behaviour of any individual molecule is much too complex an affair to follow. In any case it probably passes through the most varied conditions in any finite period of time. Further, this equal partitioning of the energy among the various degrees of freedom is a result dependent on the complete truth of the dynamical principles as laid down by Newton and extended by Lagrange and Hamilton.

Now let us turn to the behaviour of the ether which is situated within our enclosure where the walls are at a constant temperature. The trains of radiation passing through it involve periodic changes at every point of this ether. The old view, so skilfully developed by Young Fresnel, Green, MacCullagh, Lord Kelvin was that this periodic change is actually a vibratory movement of the ether, which is pictured as a material combining properties of rigidity, incompressibility and fluidity in a fashion hard to reconcile with our preconceived notions based as they are on the actual properties of matter as we directly apprehend it, Maxwell, taking up the ideas of Faraday and putting an

elegant mathematical dress upon them, turned away somewhat from such hard and fast physical ideas of radiation. Instead he developed a system of equations based essentially on electromagnetism, which he claimed had to be satisfied by the particular physical property in the ether whose periodic variation accompanies the transmission of energy through space. Despite this fact, his methods are quite consistent with the notion that a finite body of the ether can possess degrees of freedom, and that the average energy of any volume of the ether can be calculated in a manner analogous to the calculations carried out for ordinary matter. Furthermore his equations, whose importance in the Physics of the last fifty years cannot be overestimated, are based on the truth of Newtonian Dynamics, and ultimately involve an equipartitioning of energy among the various degrees of freedom of the ether just as the Lagrange-Hamilton equations involve it for the molecules of matter. The idea of degrees of freedom is difficult enough for the non-mathematician to grasp in the case even of such a tangible thing as solid matter. In the case of the ether it appears very elusive indeed. It will perhaps be best to illustrate by the older view of ethereal movement; at all events the conclusions are consistent with those developed by means of Maxwell's equations. Consider a string stretched between two points. Such a string is capable of many ways of simple vibration, several of which I illustrate by these drawings on the board. First, it may vibrate as a whole between the indicated forms; then it may vibrate in two halves with the middle point always at rest. It is known that the frequency of vibration of any point on the string is in the latter case double what it is in the former, i.e., double the fundamental frequency. Then it may vibrate in three different segments, with two "nodes," and a frequency three times the fundamental; and so on. Theoretically there is no limit to this exact division of the string into so many parts with an accompanying simple type of vibration, if we regard the string as a perfectly continuous piece of matter. If, however, we regard it, as we must do on the

molecular hypothesis, as a group of discrete particles, there is an upper limit to the number of such types of motion, viz., the number of particles itself. Be that as it may, we have the concept of a string which may vibrate in certain simple fundamental ways with frequencies which progress in the ratio of the whole numbers. Thus if the fundamental vibration has a frequency f times per sec, the others are $2f$, $3f$, $4f$, etc. up to the limit prescribed by the structure of the string. Any vibration of the string, however complex its nature, can be considered as the sum of a number of their simple vibrations, each one with an appropriate amplitude or intensity. Hence these simple types of vibration constitute the "degrees of freedom" of the string, and you will observe that there are exactly n degrees of freedom whose frequencies are not greater than n times that of the fundamental, that is, the number below a certain frequency is proportional to that frequency. Now let us make a further step. Consider a stretched skin in the form of a square, instead of a string; it has also certain simple types of vibration which may be roughly considered as a blend of those belonging to all the strings which we could cut out of the skin by lines parallel to one pair of sides with those belonging to strings cut out by lines parallel to the other pair. This blending makes the total number of such simple types, i.e., of degrees of freedom, whose frequencies are not greater than a certain frequency to be proportional to the square of that frequency. Finally, if we consider a cubical lump of elastic material, its fundamental mode of vibration and all the simple types constituting its "overtones" are a blend of three sets of linear types, and it appears that the number of all the simple types whose frequencies are not greater than a given frequency is proportional to the cube of that frequency. Now, it is this lump of elastic material which we are to take as our model of the ether. The finite volume of ether enclosed within the constant temperature walls is at any moment in a definite state of agitation following on the transmission of vibrations through it from the walls of the enclosure. This state of agitation is the

sum of an enormous number of simple vibrations, each one of which corresponds to one degree of freedom of this volume of ether. Owing to the uncontrolled motions of the molecules of the walls and their internal parts, the motion of the ether is just as uncontrolled. The actual state of one tiny portion of it at a defined instant is as unpredictable as that of a single molecule, but the energy of the whole should be given by the principle of equipartition, i.e., for every degree of freedom there should be energy of radiation always present of amount

$$\frac{2}{3}\, a\, \mathrm{T} \text{ ergs}$$

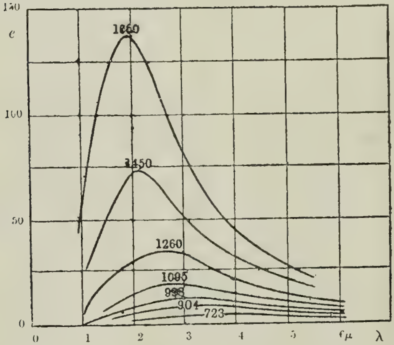
where T is the temperature of the enclosure, $\frac{1}{3}\, a\, \mathrm{T}$ ergs being the average kinetic energy per degree of freedom and $\frac{1}{3}\, a\, \mathrm{T}$ being the average potential energy. Now, as I have stated above, the number of degrees of freedom, or simple types of vibration possible for the ether in the enclosure is first of all proportional to the volume, as one would expect, and then to the cube of the highest frequency possible. The question naturally arises—is there any highest frequency? If the ether is to be regarded as an absolutely continuous medium, there is not; and this leads to the conclusion that the number of degrees of freedom of the ether is genuinely infinite, not merely enormously large like that of the walls of the enclosure; and this means that in the steady state corresponding to a definite temperature while there would be a finite amount of energy in the walls, there would be an infinite amount in the enclosed ether, a statement which really means that the only possible steady condition would be one in which all the energy would be in the ether and none in the walls, which would therefore be at absolute zero.

But let us waive this difficulty; yet we are not freed from anomalies. Let us put an upper limit to the types of vibration which the ether may have. Experiment has shewn that the ether, even if it has a structure, is nothing like as coarse-grained

as ordinary matter. The frequencies corresponding to X-rays are of the order 3 trillions per sec.

To avoid much use of algebraic symbols let me make use of graphical methods. The curve which I draw on the board is to be interpreted thus. Lengths along the horizontal axis are to be considered as proportional to frequencies, so that a point on this axis indicates a definite frequency. The lines drawn up from two such points enclose with the axis and the curve a quasi-rectangular area. Now the curve is so drawn that this area is proportional to the number of degrees of freedom in, say, 1 c.c. of the ether whose frequencies lie between the limits indicated by the two points. The area bounded by the curve and the axis up to a particular vertical line is proportional to the cube of the length along the axis up to this line, which agrees with the rule concerning the number of degrees of freedom of the ether mentioned above. The curve as a matter of fact is a very well-known one, being a parabola. If we are then to partition the energy of the ether in a constant temperature enclosure equally between all the degrees of freedom, it follows that the quasi-rectangular strips may be taken to be also proportional to the amount of energy in the ether corresponding to vibrations with frequencies between the limits indicated by the two points ; and the whole energy in the ether is to be proportional to the whole area under the curve up to the point corresponding to the maximum frequency possible if we choose to impose such a limit which, as I have stated, must be in the trillions at least. Well, this conclusion is absolutely contradicted by facts. It is possible to determine what is the partitioning of the energy among the frequencies. A hollow vessel is maintained at a steady temperature (by electric heating if the temperature is very high). A small hole is opened in its wall, which permits some of the radiation to emerge. This radiation is a fair sample of that existing inside the vessel and can be analysed in the usual way. It is known that this radiatiou, "full radiation" as it is called, is independent of the material of the walls so long as these

are not perfectly reflecting for any qualities of radiation, a conclusion which can be arrived at theoretically, and is substantiated by experiment. The results of the analysis of such full radiation and the amount of energy within defined limits of frequency or wave-length are indicated in the slide* which give curves for a



Spectral Energy Curves of Full Radiation.

(Lummer and Pringsheim).

Fig. 4.

variety of temperatures, the horizontal lengths being taken as proportional to wave-length, instead of frequency. When drawn so as to make the horizontal lengths proportional to frequency,

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* Fig. 4.

any one of these curves takes the form which I put on the board*

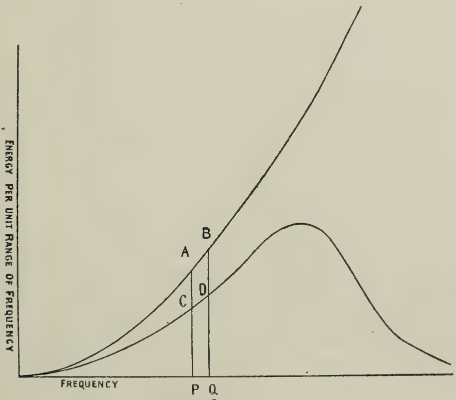

FIG. 5

beside the original parabola. The discrepancy between theory and experiment could not be more forcibly illustrated. Instead of the greater part of the energy residing in vibrations of very high frequency, it is largely concentrated in vibrations around a certain mean frequency, this mean frequency changing to a higher value, with, of course, a shorter wave-length, as the temperature of the enclosure rises. To emphasise the point still further, let me show you the energy curves of the radiation from the sun (freed from the absorption of the solar and terrestrial atmospheres), the electric arc, and a gas flame, all sources which approximate closely to the condition of "full radiators." The same type of curve with its maximum peak appears just as in the previous slide. Let me also give one numerical illustration which can be deduced from such curves. A mass of iron at the freezing point of water is situated inside an enclosure whose walls are

* Fig. 5.

perfectly impervious to radiation. According to the theoretical results the iron ought to lose energy continually until its temperature became practically absolute zero, and the whole energy of the system had passed into the surrounding ether, and was contained almost entirely in those vibrations of the ether which were of the very highest frequency. So far from this actually happening, the experimental evidences indicates with some certainty that a steady state is rapidly reached in which the density of the energy in the ether is about 40 millionths of an erg per c.c., while that in the iron is about 8,000 million ergs per c.c. Actually all the energy, with an infinitesimal exception, resides in the comparatively few degrees of freedom of the iron, while the enormously greater nnmber of degrees of freedom of the ether are almost devoid of energy. Nothing further from equipartition between the matter and the ether could hardly be imagined.

Here then we are faced with a serious discrepancy. It is not the only one. There is another one concerned with the division of the energy between the degrees of freedom of the matter itself, and there are some concerned with such points as the electrical and thermal conductivities of the metals. Time does not permit me to enter into any account of these, but this much may be said : if we can find the key to the first riddle it will in all probability give us the answers to the others. It is the master problem, the interaction between ether and matter.

To sum up the situation as it presents itself to us, we see that the application of Newtonian Dynamics, as embodied in Maxwell's equations, to the interaction between matter and the ether (the latter being regarded as a continuous medium, or at least one with an excessively fine structure) leads to a partition of energy between the ether and the matter in a constant temperature enclosure, and also a partition of the energy in the ether itself among its various simple types of vibration, which is wholly at variance with experimental observation. Nothing could be further from equipartition than the state graphically represented on the slides just shown.

To meet this difficulty two courses seem immediately possible, one is to abandon the principle of equipartition, but still retain the classical dynamical principles and discover the flaws in the chain of inference which leads from the latter to the former. Such a course is perfectly logical, and finds favour among the older and more conservative of physicists. But on the whole, opinion seems to be turning generally to a more drastic solution, to a denial of the complete validity of Newtonian Dynamics itself. It must be confessed that it is not only on these matters that the foundations of classical dynamics have shown signs of being no longer able to support the superstructure of our knowledge, and of requiring something broader still to rest on. It is not surprising that in this particular difficulty attempts are being made to arrive at a set of principles of wider application than any contemplated by Newton or his immediate followers. To the treatment of the movements of our solar system and of bodies of ordinary dimensions on the earth's surface, the Newtonian dynamics has shewn itself admirably adapted, although there are one or two minute discrepancies which have obstinately resisted explanation.

When we pass into the region of molecular, atomic and electronic motion and the transference of energy from such exiguous bodies to the ether, we are dealing with orders of magnitude far removed from those contemplated in gravitational theory. Bodies of excessively minute dimensions but possessed of enormous speeds are our material. The 30 kilometres per second or so of our earth's motion round the sun is a very snail's pace compared to the speed of electronic movement with which we are now-a-days familiar, attaining in some cases almost to the speed of light, 300,000 kilometres per second. There is little to marvel at, if it should turn out that we want new laws to co-ordinate the new knowledge in regions so remote from our customary perceptions, laws to which Newton's principles constitute an excellent approximation under the conditions for which they were designed.

Unfortunately, in this direction, little has been attained so far. If we are to rebuild, we are still awaiting our Newton. Into the mass of conflicting material one tentative principle has been thrust. It is little more than a new proposal as to the partitioning of energy, with but a small physical basis for its support. Yet its undoubted success in calculating the partitioning of energy leads one to believe that it will perhaps one day occupy a position of some importance in the new structure which has to be raised. I will treat it first as a mere principle of partitioning, and then say a few words as to the manner in which its originator, Professor Planck, of Berlin, and his school seek to justify it.

Return to the two diagrams. The parabola representing the partitioning of energy on the older assumptions and the peaked curve representing the actual facts. Each curve is supposed to be drawn for a definite temperature, T. Professor Planck's first step was the discovery of the relation between these two curves and of a mathematically elegant expression for it. Take two near points P and Q on the frequency axis; they represent two definite frequencies separated by a small range of frequency: the amount of energy in unit volume of the ether corresponding to the types of vibration between these two frequencies would be represented by the narrow quasi-rectangle $PQBA$ on the equipartition basis; it is actually represented by $PQDC$. Now it appears that the ratio between AP and CP can be expressed by a simple formula depending on the value of the temperature T, and the value of the frequency represented by the point P; let us call that n vibrations per second, which of course corresponds to a wave-length obtained by dividing the speed of light by n. The expression for the ratio further involves the constant a already used (with a value close to 200 billionths, you will remember), and a new universal constant, "Planck's constant," with a value about 6,500 quintillionths ($6{\cdot}5 \times 10^{-27}$). The extreme importance of this new constant for purposes of calculation is undoubted. There must be some physical basis for it,

though what it is forms a matter rather of speculation than of sure knowledge at present. But I will come to that in a moment. To proceed. With this set of symbols, two of them absolute universal constants, two of them standing for measures of definite physical properties, let us calculate the number :

$$3hn/2aT$$

where h stands for Planck's constant.

Call this calculated number r. This number r has, of course, a definite value for each point P on the frequency axis, so long as we are considering a definite pair of curves corresponding to a definite temperature.

Now, Planck has pointed out that the ratio AP to CP is equal to the sum of the series

$$1 + r/2 + r^2/6 + r^3/24 + r^4/120 + \textit{etc. ad infin.}$$

That is not the most elegant way of putting this ratio. Those of you who have some knowledge of mathematical functions will recognize this series as

$$(e^r - 1)/r$$

Where e is Naperian base of logarithms.

Of course the ratio varies as we pass along the corve, for r is a different number at different parts of the curve.

This is a new principle of partition. It has been discovered that its applicability is not confined to partition of energy in the ether alone. Indeed it is its application to the distribution of heat energy among the types of vibration of solid bodies that has constituted one of its triumphs, and first brought it seriously into consideration.

To state it once more—when apportioning vibrational energy among the degrees of freedom of any substance, ethereal or material, at a definite temperature, one first of all estimates the amount to be assigned to each narrow frequency range by the equipartition principle and then divides the result by the expression.

$$(e^r - 1)/r$$

where r is the frequency temperature number calculated as above.

It appears that if n is small enough or T large enough, the value of r is so small that the divisor given above is little different from unity and so for high temperatures or frequencies of vibration not too great the equipartition principle nearly holds; but at low temperatures or high frequencies it is utterly at variance with the facts. This in itself is but one way of saying that, under certain restricted conditions, Newtonian dynamics is an excellent approximation to truth.

It remains for me to give you a brief statement of the manner in which Planck endeavours to justify this partitioning of the energy. He does so by introducing the hypotheses of discontinuous or spasmodic radiation. Now, this hypothesis can find no secure position in the general framework of electromagnetic theory as built on Maxwell's Equations. According to modern views as to the structure of the atom, there is no doubt that the electrons of the atom are the sources of all those high frequency radiations for which the principle of equipartition proves such a failure. The result of applying orthodox theory to the actions between electrons and the ether is to demonstrate that electrons cannot radiate energy if they are at rest or in uniform motion. They must be moving with velocities variable either in speed or direction, or both. Now, such variable motion is an obvious feature of rotation in the quasi-planetary orbits around the atomic nucleus; it is also a feature of electron motion when they are ejected from the atom by the action of ultraviolet light or X-rays. At all events, according to classical theory, electrons whirling in their atomic orbits should be continuously radiating energy. This constitutes something of a difficulty, for such continuous radiation of energy must mean a gradual contracting of the orbit and a gradual absorption of all the electrons into the necleus with a consequent change in the properties of the atom which is certainly not justified by facts. The ordinary phenomena of magnetism, and the action of magnetic fields on sources of monochromatic light give powerful evidence of the permanent and undiminished intensity of such electronic whirls

in all atoms, and this permanency is hard to reconcile with the gradual loss of energy by the electron deduced by theory. True the full force of the argument can be somewhat abated by postulating that there are a considerable number of electrons in any one orbit following each other round in a stable ring ; for under such circumstances it appears that the rate of radiation is greatly reduced.

Planck's hypothesis is this. He assumes that there are electrons in the atom—"resonators" he calls them—which oscillate without radiating in this continuous way. He also assumes, to take his later views, that these resonators can absorb energy in a continuous manner from the energy of the surrounding ether by reason of the electrical forces inherent in all radiant energy according to the electro-magnetic theory of light. Such absorption without emission could not go an for ever. Radiation from the resonator must occur some time or other. Planck postulates that this emission instead of being continuous is jerky or spasmodic. He assumes that there are certain critical stages in this loading up of energy when the resonator may suddenly put out its whole content of energy in one rapid rush as it were. These critical stages occur when the resonator possesses exactly a definite multiple of a definite "quantum" of energy. It is in the amount of this quantum that Planck's h constant makes its appearance. The resonator will, of course, have a definite frequency—n per second, let us say ; the quantum of energy for this resonator is hn erg. Suppose we conceive the resonator devoid of energy, it begins absorbing from the surrounding ethereal energy ; presently it is loaded up with a value hn, it may radiate then ; it cannot do so before that moment (according to Planck) ; it may fail to radiate at this moment ; it then keeps on absorbing until it attains an energy $2\ hn$; it cannot emit in the interval, but it may radiate at this moment ; again if it fails to do so it keeps on absorbing and cannot radiate until its energy reaches $3\ hn$, and so on. Radiation can only occur at certain well-defined and discrete

states ; the chance of the resonator emitting at the energy hn is greater than its chance of passing this critical state and radiating at the energy $2\,hn$, and so on. Planck assumes a certain law of chance for the attainment of these successive stages which is plausible enough ; but one point must be most strongly emphasized ; for it is vital in his reasoning. At whatever multiple of the quantum radiation occurs, the whole amount pours out suddenly ; nothing can check or prevent this total radiation. Here is the very essence of the discontinuity.

The particular form of the hypothesis which I have outlined above is not the only one possible, in fact it is not quite the form first propounded by Planck himself. Also other workers have abandoned the particular radiating mechanism postulated by Planck, viz., the resonator, and employed the ordinary orbital whirls of electrons. But all have to assume somewhere or other this feature of discontinuous emission of energy from whatever radiating mechanism they employ. It is possible to do without discontinuous absorption, but discontinuous emission there must be and in amounts which must be multiples of the quantum of energy corresponding to the frequency of the mechanism. Perhaps you may think that because of the extreme smallness (compared to our customary standards) of a quantum of energy even for very high frequencies (an amount equal to about six billionths of an erg [6×10^{-12}] for a frequency of 1,000 billions [10^{15}], that discontinuous outputs in such exiguous quantities would practically amount to continuity. Such a view cannot be maintained. It must be remembered that the scale of dimensions we are dealing with here is quite distinct from that of daily phenomena which appeal directly to our senses. It is all a matter of comparison, and the quantum which I have just mentioned is certainly 100 times as great as the average heat energy of a molecule at normal temperatures, and it is this latter amount which is the natural quantity of energy for us to consider when we are concerned with the comparative largeness or smallness of the amount of energy which is converted from one form

to another in these small scale phenomena. Besides, as I indicated at the beginning of this paper, it is not in the magnitude of the phenomena nor in its extreme brevity that the discontinuity arises. In order to obtain by logical reasoning Planck's partition of the energy, which is undoubtedly extremely near to the truth, and avoid equipartition, which is certainly far from it, we are bound to assume some hypothesis concerning the radiation of energy for which we have no basis in our fundamental principles. It seems necessary to postulate a picture of the atom structure such as the following. Around the positively charged nucleus of the atom we have negative electrons rotating in orbits. On the older views the positions of these orbits could change continuously as the electrons gained or lost energy in a continuous manner. On the new idea, we must consider the possible orbits as discrete and well separated from one another. While an electron moves in one of these stable paths, its motion can be calculated by the orthodox dynamical rules; thus for a single electron whirling round a single nucleus (the usual view of the hydrogen atom), any of these paths would be the usual planetary ellipse. While in this path the energy of the electron remains constant; there is no radiation of energy and no absorption. Some critical condition arises due to external influences and the electron leaps suddenly from one orbit to another. As the energies of the electron in two orbits are different, the electron must part with or absorb some energy in the transit, the amount being quite definite and determined by the particular two stable orbits considered. This amount is emitted or absorbed as vibrational energy of a definite frequency, and here the significance of Planck's constant comes in, for the frequency of the radiation emitted or absorbed must be such that when multiplied by this constant the result is the amount of energy in question. This is a view of atom-structure which is receiving considerable attention of late. You will see that it postulates both discontinuous absorption and emission. Planck, himself, being reluctant to abandon any more than was necessary of the older theory contented himself with developing a theory of "resonators"

which could absorb continuously and radiate discontinuously. The truth is that there is at present little to choose between the two views. It should be remarked that the former view could be pushed still further and interpreted as the result of the fact that there was an atomicity in energy itself, a speculation that has been more or less implicit in the recent work of some of the English school of Physicists, notably Sir J. J. Thomson. However, there does not appear to be any phenomena yet which actually compel us to adopt such a revolutionary view ; but it is doubtful if we will be able to escape from some form or other of Planck's hypothesis. In itself it may turn out to be only one result of a new scheme of dynamics, of which we are now getting the first inklings in the case of these small scale vibratory occurrences.

The key-note of the new mechanics is discontinuity. According to it "A physical system is only susceptible of a finite number of distinct states. It leaps from one of these states to another without passing through a continuous series of intermediate states." Such a statement bristles with difficulties, which even the least conservative of minds may well shrink from facing. Yet it seems that only by solving these difficulties can real progress in physical science be effected.

It may not be out of place to point out, in conclusion, that this development in physical theory is almost contemporaneous with a movement in philosophy, associated with the name of Professor Bergson, which regards the intellect as unable to grasp the reality of Life ; as being only designed to isolate discrete states and apply logical principles to their relations one with another, but unadapted to apprehend the continuous flow of "becoming things." It is a well known fact that in any historical epoch, a central idea seems to permeate all human institutions and activities ; and the parallelism between Bergson's view and the quotation in the previous paragraph, which is H. Poincaré's generalised form of the quantum hypothesis, seems sufficiently striking to call for comment.

ANNUAL REPORT, 1917-18.

The Council in submitting the Annual Report of the Ninety-seventh Session of the Natural History and Philosophical Society, desire to express their warmest thanks to the lecturers who delivered the following lectures throughout the Session :—

10th November, 1917. In Museum, College Square North.
"SOME MODERN METHODS OF PROTECTION AGAINST DISEASE" :—Professor St. Clair Symmers, M.B.

11th December, 1917. In Museum, College Square North.
"SOME RECENT APPLICATIONS IN CHEMISTRY : I. IN PEACEFUL PURSUITS. II. IN WARLIKE PURSUITS" :—Professor William Caldwell, M.A., D.Sc.

8th January, 1918. In Museum, College Square North.
"THE GIANTS' RING, AN ACCOUNT OF THE RECENT EXCAVATIONS" :—Mr. H. C. Lawlor, M.R.I.A. Followed by a short paper on the same subject, by Professor R. A. S. Macalister, M.A., D.Litt, F.S.A. (Cantab).

12th February, 1918. In Museum, College Square North.
"FOLK LORE OF PLACE NAMES" :—Professor Sir John W. Byers, M.A., M.D.

12th March, 1918. In Museum, College Square North.
"THE PSYCHOLOGY OF TELEPHONING" :—Mr. John Lee, M.A., Postmaster, Belfast.

9th April, 1818. In Museum, College Square North.
"DISCONTINUITY IN NATURE AS ILLUSTRATED BY THE PHENOMENA OF RADIATION" :—Mr. James Rice, M.A., Lecturer on Physics, Liverpool University.

The lectures were much appreciated by large audiences.

FORMATION OF AN ARCHAEOLOGICAL SECTION.

During the Session an Archaeological Section in connection with the Society was formed, with the object of furthering the study of Archaeology and Antiquities, more especially in the neighbourhood of Belfast, by investigation and excavation of ancient monuments of particular interest, and the recording in the Society's journal of proceedings, the results of work done. It is satisfactory to report that the section is meeting with much success.

PROCEEDINGS OF KINDRED SOCIETIES.

Reports of the Transactions and Proceedings of Kindred Societies, both home and foreign, were received during the past Session, and exchanges have been made in all cases. A list of the exchanges will be attached to the Report.

MEMBERSHIP.

As a result of the new scheme of membership whereby subscribers of 10/- annually are admitted to the privileges of membership, and the formation of the archaeological section, the roll of membership has been increased. The Council desire to bring before the members the desirability of introducing new members, and thus widening the influence and increasing the Society's resources for the development of scientific and antiquarian research. Application for membership, and copies of the Report and proceedings of the Society for distribution amongst likely members, can be had on application at the Museum, or from the Assistant Secretary, 10 Donegall Square East.

OBITUARY.

The Council records with sorrow the death of Mr. William T. Braithwaite, an old member of the Society, who evinced a

keen interest in its preceedings ; also of Mr. W. H. Patterson, one of the oldest members, who had frequently contributed to the Society's proceedings, Dr. St. Clair Boyd, and Mr. Emerson C. Herdman, D.L.

COUNCIL.

The following members of the Council retire :—Mr. John M. Finnegan, B.A., B.Sc. ; Professor J. A. Lindsay, M.A., F.R.C.P. ; Henry Riddell, M.E., M.I.M.E. ; Robert M. Young, M.A. ; Professor St. Clair Symmers, M.B.

The following were elected at Annual Meeting, held in Museum, under Presidency of Mr. R. M. Young, M.A., on Tuesday, 12th November, 1918, on the motion of Mr. Elliott, seconded by Mr. Lawlor :—Mr. John M. Finnegan, B.Sc. ; Professor J. A. Lindsay, M.A., F.R.C.P. ; Mr. Henry Riddell, M.E., M.I.M.E. ; Professor St. Clair Symmers, M.B.

The following Statement shows the position of the Funds of the Archaeological Department at the date of closing of the accounts. Those funds are merged in the account above given which appears in the form required by the Local Government Board :—

Dr. CASH.	£	s.	d.	CONTRA. Cr.	£	s.	d.
1917.							
May 14.				May 13.			
Surplus from Giants' Ring Fund, collected for exploration purposes ...	£28	16	4	H. C. Lawlor, for Excavation	6	11	6
Sectional Subscription ...	10	8	0	Balance ...	42	12	10
Subsidy from parent Society on forty new members ...	10	0	0				
	£49	4	4		£49	4	4

Cash in hands of Treasurer, £42 12s. 10d. A number of subscriptions have been paid in since closing the accounts, and there are certain small liabilities still undischarged. These will appear in the accounts for current year. The subsidy given above is calculated for the present purpose on the number of new members joining the Society.

HENRY RIDDELL,
Treasurer.

EDUCATIONAL ENDOWMENTS (IRELAND) ACT, 1885.

The Accounts of the Belfast Natural History and Philosophical Society for the year ended 30th June, 1918.

Dr. — **Cr.**

CHARGE.

	£	s.	d.
To Balance as per last Account	£1	1	0
,, Subscriptions	122	10	4
,, Dividends	28	14	4
,, Rents	150	0	0
,, Miscellaneous Receipts, viz. :—Returned, I. Tax	7	16	9
,, Balance against Account on 30th June, 1918	195	11	10
Total,	£505	14	3

LIST OF SECURITIES.

	£	s.	d.
4½% Debenture York Street Flax Spinning Co., Ltd.	£400	0	0
5% War Loan 1929-47	305	5	3
	£705	5	3

DISCHARGE.

	£	s.	d.	£	s.	d.
By Maintenance of Premises, &c.				£340	7	11
,, Rent, Rates and Taxes				29	14	8
,, Salaries				20	0	0
,, Other Payments, viz. :—						
Printing and Stationery	£68	5	11			
Advertising	16	12	0			
Postages, &c.	11	3	4			
Audit Fee	1	1	0			
Check Book	0	2	1			
Photos, drawings, and lantern work	2	4	9			
Insurance	1	6	6			
Excavating Antiquarian Remains	6	11	6			
Collecting Subscrtptions	4	5	6			
Interest paid Bank	3	19	1			
				115	11	8
Balance per Bank Book	£195	11	10 (Debit)			
Total,				£505	14	3

We certify that the above is a true Account.

ROBERT M. YOUNG, Governor.
HENRY RIDDELL, Accounting Officer.
20th July, 1918.

I certify that the foregoing Account is correct.

D. L. CLARKE, Auditor.
23rd August, 1918.

EXCHANGES.

BERGEN (NORWAY)—Publications of the Bergen Museum.

BRIGHTON—Annual Report of the Brighton and Hove Natural History and Philosophical Society. 1917.

CALCUTTA—Memoirs of the Geological Survey of India.

„ Records of the Geological Survey of India.

„ Report of the progress of Agriculture in India. 1916-17.

CALIFORNIA—Publications of the University of California.

CAMBRIDGE (U.S.A.)—Annual Report and Bulletins of the Cambridge Museum of Comparative Zoology.

CAMBRIDGE—Proceedings of the Cambridge Philosophical Society.

EDINBURGH—Proceedings of the Royal Physical Society.

„ Proceedings of the Royal Society of Edinburgh. 1916-17.

GENOA—Rivista ligvre di Scienze Lettere ed Arti.

GLASGOW—Transactions of the Geological Society of Glasgow.

„ Proceedings of the Royal Philosophical Society of Glasgow. 1916-17.

KANSAS—Science Bulletin of the University of Kansas.

LIMA (PERU)—Boletin del Cuerpo de Ingenieros de Minas del Peru.

LONDON—Continentality and Temperature, by C. E. P. Brooks, Meterological Office.

„ Quarterly Journal of the Royal Microscopic Society.

„ Memoirs of the Royal Astronomical Society.

„ Quarterly Journal of the Geological Society.

„ Report of the British Association. 1917.

LOUSANNE—Bulletin de la Societe Vaudoise des Sciences Naturelles.

MELBOURNE—Proceedings of the Royal Society of Victoria.

MEXICO—Anales del Instituto Geologico de Mexico.

MICHIGAN—Annual Reports of the Michigan Academy of Science. 1915. 1916.

NEW HAVEN—Transactions of the Connecticut Academy of Art and Sciences. 1918.

NEW ORLEANS—Sixth Biennial Report of the Board of Curators of the Louisiana State Museum. 1916-17.

NEW YORK—Annals of the New York Academy of Sciences.

,, The Geographical Review. Monthly.

OHIO—Bulletin of the Ohio State University.

,, The Ohio Journal of Science.

OTTAWA—Memoirs of the Canadian Geological Survey.

,, Memoirs of the Geological Survey of Canada, Department of Mines.

OXFORD—Report and Proceedings of the Ashmolean Natural History Society.

PHILADELPHIA—Proceedings of the Academy of Natural Sciences of Philadelphia.

,, Proceedings of the American Philosophical Society.

PUSA (INDIA)—Scientific Reports of the Agricultural Research Institute. 1916-17.

SAN FRANCISCO—Proceedings of the California Academy of Science.

STAVANGER (NORWAY)—Report of the Stavanger Museum. 1916.

TORQUAY—Journal of Torquay Natural History Society. 1918.

TORONTO—Transactions of the Royal Canadian Institute.

WASHINGTON—Annual Report of the Smithsonian Institution.

,, Annual Report of the United States National Museum.

,, Bulletins of the Bureau of American Ethnology.

,, Bulletins of the Smithsonian Institution.

,, Contributions from the United States National Herbarium.

,, Proceedings of the United States National Museum.

,, Smithsonian Institution Miscellaneous Collections.

,, Year Book of the United States Department of Agriculture. 1917.

YORK—Annual Report of the Yorkshire Philosophical Society. 1917.

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Belfast Natural History and Philosophical Society.

Society Founded 1821.

PRESIDENT, PROFESSOR W. ST. CLAIR SYMMERS, M.B.

NINETY-SEVENTH SESSION.

The Council of the Belfast Natural History and Philosophical Society have founded an Archæological Section and a separate Committee of the Section has been formed. The object of the Section is to carry out more fully the work that has been done, to a limited extent, through grants made by the Society for several years. This work has been the investigation and excavation of monuments of antiquity in the neighbourhood, and the recording and publication of the results of such investigations. The preservation or restoration, where desirable, of monuments examined, and the general encouragement of the study of local Archæology, and the history, manners and customs of the ancient inhabitants of the North of Ireland will also form part of the aims of the Section.

The Committee of the Section will be glad to hear from any persons who wish to recommend objects of antiquity for investigation, and such recommendations will be carefully considered.

The Committee especially appeal to members of the Society and others, to encourage general interest in the objects of the Section. There are undoubtedly many people, especially in country districts, who have a general interest in Archæology, but have not the opportunity of cultivating their interest and extending their knowledge owing to the want of a centre such as the Archæological Section is intended to supply. Members will be entitled to receive, free of charge, all publications of the Natural History and Philosophical Society, to enjoy the use of the Library, and attend all its Lectures and Meetings.

The Subscription has been fixed on a scale to be burdensome to none, and it is needless to point out that the success of the Section can largely be assured by those connected with it doing all in their power to increase the membership and general interest in its objects.

ARCHÆOLOGICAL SECTION.

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Sir Charles Brett, Gretton, Belfast.

Hon. Treasurer—
Mr. Henry Riddell, M.E.,
83 Myrtlefield Park,
Belfast.

Hon. Secretary—
Mr. H. C. Lawlor, M.R.I.A.,
8 Windsor Avenue,
Belfast.

GENERAL RULES.

1. The object of the Archæological Section is to investigate, illustrate and record particulars of monuments of antiquarian interest in Ireland, more especially within a radius of 75 miles from Belfast, and generally to encourage and pursue the study of Archæology.

2. The Section shall consist of a Chairman, Treasurer, Secretary and Members, all of whom must be members of the Belfast Natural History and Philosophical Society.

3. The management of the business of the Section shall be entrusted to an Executive Committee of twelve members, of which the President, Treasurer and Secretary of the Society shall be ex-officio members. The Chairman, Treasurer and Secretary of the Section shall also be ex-officio members, and they and the remaining members of the Executive Committee shall be elected annually at the Annual General Meeting of the Section.

4. The First General Meeting of the Section shall be held in February, 1918, and the Annual General Meeting shall take place each November, on dates to be arranged by the Executive Committee.

5. Members of the Society shall be admitted to the Section on election by the Executive Committee, and candidates must secure a majority of at least three quarters of the votes of those present at the Executive Committee Meeting.

6. The amount of the subscription to the Section (in addition to the subscription to the Society*) shall be voluntary, but not less than 5/-, payable on election, and afterwards annually on 1st November; but nothing in the foregoing shall prevent the Executive Committee electing members free of subscription if they deem it advisable.

7. The research work of the Section shall be decided upon by the Executive Committee, though it will be open to any person to suggest to the Committee any desirable subject of antiquarian interest for investigation. Any objects of antiquity discovered in any investigation, other than treasure trove, shall be handed over to the Society for inclusion in their collection in the Museum.

8. The works of investigation carried out under auspices of the Section shall be recorded in written reports. These reports will be submitted to the Publication Committee of the Society, who will recommend to the Council whether, and in what form, they will be published in their Proceedings and Annual Report.

9. These rules may be altered or amended or added to, but only by resolution passed at the Annual General Meetings of the Section; notice of any such alteration must be handed in writing to the Secretaries of the Society and of the Section, not less than one or more than six months prior to the Annual General Meeting at which they are to be proposed.

* The Subscription payable by Members of the Natural History and Philosophical Society is 10/- per annum.

Report and Proceedings

OF THE

BELFAST

Natural History and Philosophical Society

FOR THE

SESSION 1918-1919.

BELFAST:
MAYNE, BOYD & SON, Ltd., 2 CORPORATION STREET
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1920.

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Belfast Natural History and Philosophical Society.

——o——

ESTABLISHED 1821.

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CONSTITUTION.

The membership of the Society consists of Shareholders, Members under the new scheme authorized by the Society, Annual Subscribers (Associates), Honorary Members and Honorary Associates,

A holder of one share pays an annual contribution of ten shillings ; a holder of two shares (in one certificate) an annual contribution of five shillings ; while a holder of three or more shares (in one certificate) is exempt from annual payments. Shares on which the annual payments as above are in arrear are liable to forfeiture. The Council retain the right to decline to consolidate two or more share certificates into one certificate. Members under the new Scheme are elected by the Council, pay ten shillings per annum subscription, and have the right to vote on all questions not affecting the ownership of the property of the Society.

Annual Subscribers (Associates) pay £1 1s. 0d. (one guinea), due 1st November each year in advance.

A general meeting of Shareholders and Members is held annually in May or June, or as soon thereafter as convenient, to receive the Report of the Council and the Statement of Accounts for the preceding year, to elect members of Council, to replace those retiring by rotation or for other reasons, and to transact any other business incidental to an Annual Meeting.

The Council elect from among their own number a President and other officers of the Society.

Each member has the right of personal attendance at the ordinary lectures of the Society, and has the privilege of introducing two friends for admission to such. The Session for lectures extends from November to May,

Any further information required may be obtained from the Honorary Secretary at :—The Museum, College Square North, Belfast.

BELFAST

NATURAL HISTORY AND PHILOSOPHICAL SOCIETY

PROCEEDINGS,

SESSION 1918-1919.

No. 1.

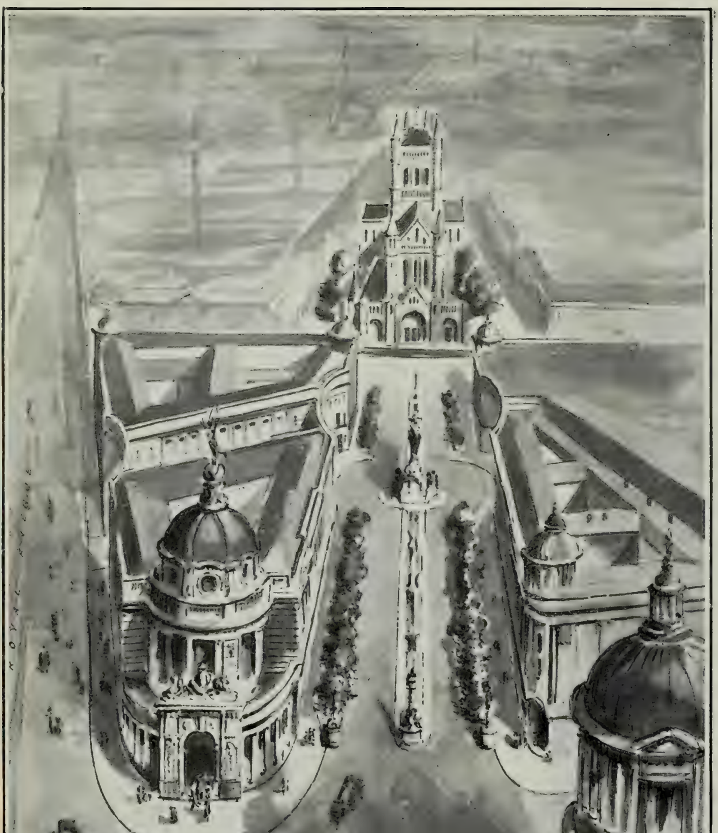
A WAR MEMORIAL.

BY MR. ALEC WILSON, J.P., M.R.I.A.

BELFAST:
MAYNE, BOYD & SON, LTD., 2 CORPORATION STREET
(PRINTERS TO THE QUEEN'S UNIVERSITY).

1919.

Fig. 2.



A Cathedral Mall.

See page 7.

10th December, 1918.

A WAR MEMORIAL FOR BELFAST.

By Alec Wilson, M.R.I.A.

I venture to offer to the citizens of Belfast a few suggestions towards a great and worthy War Memorial for this City. The suddenness with which the giant conflict has come to its end has to some extent taken us all aback, so that we are almost as unprepared for peace as we were for war. But, I take it that very shortly the civic authorities will be seeking a design for something whereby to perpetuate for many centuries the share which Belfast has taken in the vast struggle.

The loved memory of the dead : the care and restoration of the wounded and of the sick : the future well-being of those who, having fought for us, are now soon to return to us uninjured—these things cannot be separated from each other when we consider the nature of a true War Memorial—nor can either of them be separated from the idea of a general rebuilding of our social organisation.

So far as I am aware, all public memorials of war, hitherto, have been limited to the honouring, by some statue, archway, or other monumental group, of the gallant dead. Sometimes such a monument may itself have been noble and beautiful,—(more often it has been neither)—but always it has been a dead thing, a species of glorified tombstone. The opportunity is before us for creating a war memorial of a new and unique type : and my present object is to describe a few of the more essential elements in such a proposal.

It would seem that the present moment is extraordinarily opportune for a project upon these general lines. The appeal is universal, to all classes and to all creeds : there is hardly a family in Belfast that has not contributed of its men to our fighting forces : hardly a house which would not respond to the

call that we must make our Memorial worthy of those in honour of whom it is to be raised. We need something that shall touch the imagination and the soul of those that will help to create it ; that shall kindle a fire in them which shall not be quenched so long as our Memorial shall stand.

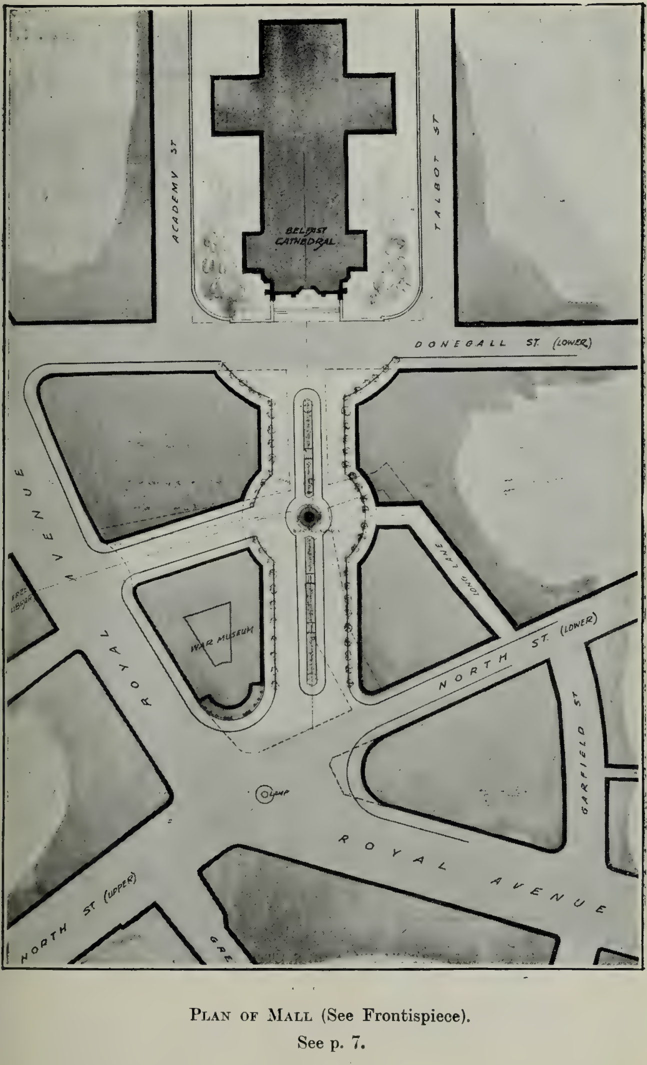
A WAR MEMORIAL INSTITUTE.

I suggest that the means whereby such an ideal could most fitly be embodied would be a War Memorial Institute of noble architecture, and occupying a commanding site. In its design and in its decoration, as in its actual working, it would be the expression at once of our Memory and of our Hope.

Memory. It must contain a permanent record of the Great War, more especially as it affected Belfast. The names and services of all our dead should be preserved in it : portraits, photographs, maps, drawings, letters, books, newspapers, flags, guns and shells : statuary : regimental records : medals : an endless variety of relics and mementoes by which future generations might be enabled, to some extent, to see these days through our eyes.

Hope. The other essential is a comprehensive plan for a Greater Belfast. Here would be books, maps, and drawings about all branches of civic activity : especially, everything dealing with Belfast should be accessible, past or future, historic or constructive. I would have a Lecture Hall, and a Publication Fund : which together should form an open court for the free discussion of every suggestion towards the betterment of our city. In this, and many other ways, we would build up a Town Plan and Survey, not rigid and inexorable,—for a rigid programme would leave too little room for elasticity and change of detail, —but upon broad lines, likely to meet the prospective needs of the community, and embodying the best thought of those most competent to guide an educated democracy in the task of its own uplifting.

FIG. 1.



PLAN OF MALL (See Frontispiece).

See p. 7.

FIG. 3.

BELFAST AS A GARDEN CITY IN 1685.

See p. 8.

As a working example, suppose we begin by choosing a site for our Institute. It is almost always hard to find a good site for a new building of any importance in a city. In this case, our Institute should be within the central half-mile circle: it should be conspicuous, and it should stand on a main thoroughfare. Preferably, it should be within easy reach of the Public Library. This would point towards a site somewhere near the corner of Royal Avenue and North Street. But, in a good Town Plan, one would not neglect to make the most of the immediate surroundings of a big new building, and of any other important buildings in the neighbourhood:—in this case the Cathedral. I therefore propose starting from the Cathedral entrance in Donegall Street, and driving out a wide Mall (FIG. 1) over the site of the present Church Street, through to Royal Avenue. I would make this Mall at least 120 feet wide, with a roadway on either side, and a formal garden in the centre. (FIG. 2, FRONTISPIECE). I would pull down the worst of the slums which still surround the Cathedral, and make room for more schools, for a residence for the clergy, for a parish hall or diocesan rooms, and for wide spaces, gravelled or grassed, in which to plant trees. The corner where this Mall would meet Royal Avenue would afford a first-rate site for the War Memorial Institute. It is a site at present occupied chiefly by public houses and mean little shops.

There is a question regarding the building of such a War Memorial in Belfast, the answer to which would, of itself, go far to show whether the true spirit of the scheme had been realized. The men who should do the actual work (manual or mental) of designing and building and ornamenting our Institute should be Irish; they are the fathers and the brothers and the sons of those in whose honour the place is to be built; they know, as no strangers could ever know (or care to know), the spirit in which our Ulster lads of all the creeds and parties went forth *voluntarily* to the war. And, more than this, their love for their own will inspire their hands to do their best work for the Institute,

while the fact that they have themselves cut the stones or carved the wood will arouse interest in them regarding the objects of the Institute itself, and so will help to make them understand that they themselves are part of the reason why it was built.

A CITY SURVEY AND TOWN PLAN.

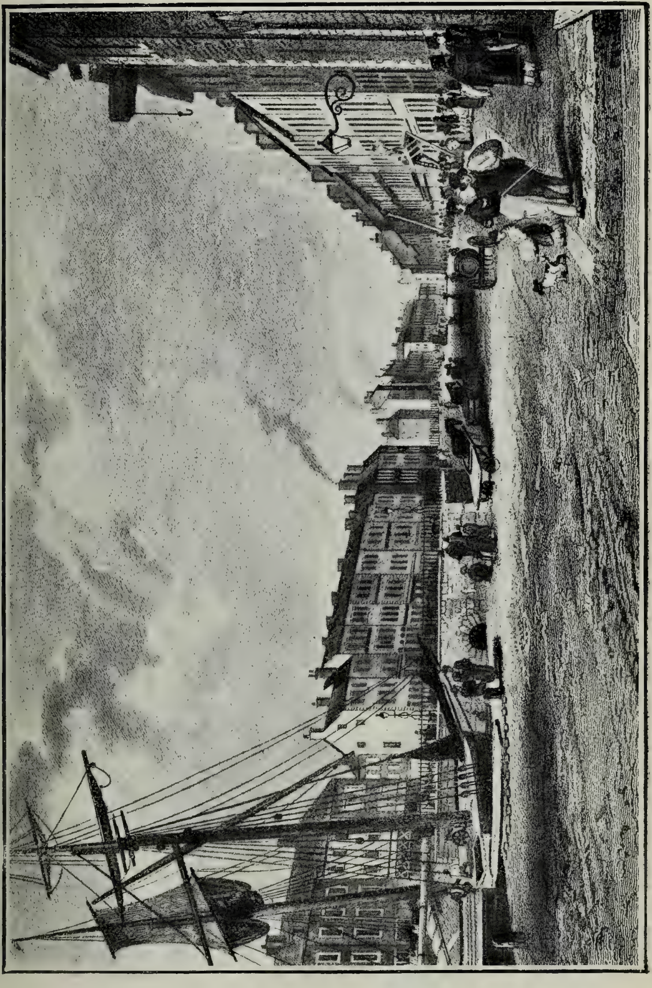
Let us presume that it is agreed to draw up a plan for the betterment of our city, and that a strong and representative committee has been brought into existence in order to carry out a preliminary survey and to suggest a constructive policy. I propose to sketch, in very brief outline, the work which would lie before such a committee.

(I.)—Past.

It is rarely possible, and seldom desirable, to discard what we have inherited from the past. Any plan worth considering at all will necessarily be built up from conditions as have been and as they are, and will take into account the history and the facts, both material and spiritual, which gave rise to those conditions.

It is, for instance, important, as well as merely interesting, even in 1918, to study the maps of the city when it was in its infancy. In 1685 (Fig. 3) Belfast was a little walled town, with its Bridge, its Castle and its Church. The map shows two notable features :—(1) a little river flows down the main street, with a roadway on either side of it, and (2) every dwelling-house in every street has its garden. So, three centuries ago, Belfast was a little "*Garden City.*" For its size, and within its limitations, it was rather well designed, and this good original plan has served us down to the present day,—and will indeed not be wholly lost as long as the city stands. For consider: when the town grew, and required facilities for increased traffic, the little "Belfast River" was built over, and so gave us our wide High Street, which still preserves the old breadth of the

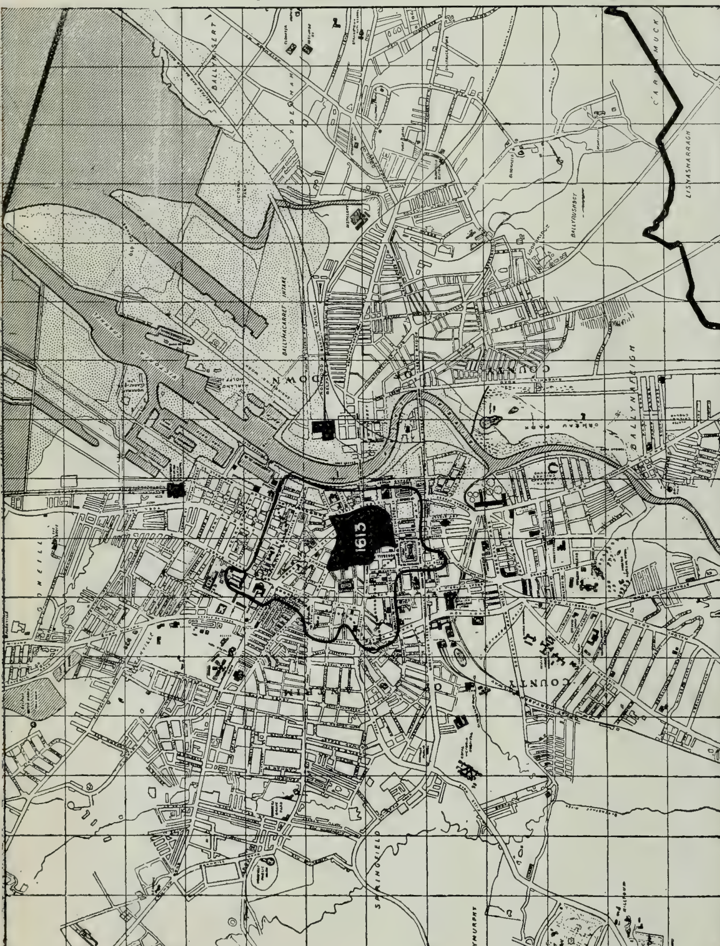
Fig. 4.



High Street, Belfast, showing portion of Old Dock about 1820.

See p. 8.

FIG. 5.



CENTRAL PART OF THE BELFAST TERCENTENARY MAP, 1613—1913.

See p. 10.

two roads with the stream between them (FIG. 4) and when the small houses needed more floor space for their trade (in those days the merchant lived in his shop), the gardens were built over and became small warehouses and factories. Later on, Donegall Place was built over the open Castle Gardens, and the wide tradition of High Street was carried on. Later still, it was customary to retain the unusual width between house-fronts, which had become so marked a local characteristic, but to use the space in front of each house for a little garden.

To this day, we can often trace the old conditions : the odd ribbon-like strips of building between Donegall Place and Fountain Street (the Carlton Restaurant is a good instance) retain the original plan of the small house with the long garden at the back : to this day, all through the centre of the city, and even in Donegall Square, there are posts and railings, or breaks in the pavement, which still indicate the edges of the old gardens.

It would be easy to enlarge upon these "civic fossils." It is sufficient for my purposes to show that a design originally good will serve for many a long day without losing all its value : I wanted especially to show how we derive our wide streets mainly from the little river which is still flowing underneath High Street, and to the good lay-out of Belfast three hundred years ago. To a large extent, the last hundred years have spoiled our good little plan : certainly we have nothing more to gain from it : and in this generation we have replaced it, so far, by—nothing. It is a fact that we owe most of our present and future difficulties in city improvement to the absence, during the city's modern growth, of any order or plan. Not merely was there no city plan, but for many and many a year nobody in Belfast ever thought of a plan as being desirable. Yet it is true that, here and there, small portions of the city were planned, piecemeal—(notably the neighbourhood of York Street, and the area around Adelaide Street)—but they were badly planned. They are on the ancient "gridiron" principle, as old as Egypt and Assyria, which has so long disfigured America, and which America

is now trying hard to get rid of. If anyone wishes to see some of the reasons why the "gridiron" plan is defective, he need only examine these sections of our own city. It is true, also, that costly improvements have been made in our streets: Victoria Street is a new creation: Royal Avenue has taken the place of the Hercules Street which I remember as a boy; but these have been, one and all of them, expensive proofs that a good original plan is a great economy, for it was the lack of good planning which made these costly schemes necessary. With a good plan it should not be necessary ever again to commit vandalisms such as we committed when we built a hotel upon the consecrated ground in which nearly all the old makers of Belfast lie buried.

This lack of plan has often cost us dear, and will long continue to do so. For lack of it, the floods in the Bog Meadows still give our gamins an occasional day's boating in our streets. For lack of it, we are still without a central railway station. For lack of it, we have no circular roads to ease the traffic through the congested centre of the town. For lack of it, Belfast Cathedral stands in a back street. For lack of it, our population per inhabited acre is about three times denser than it should be.

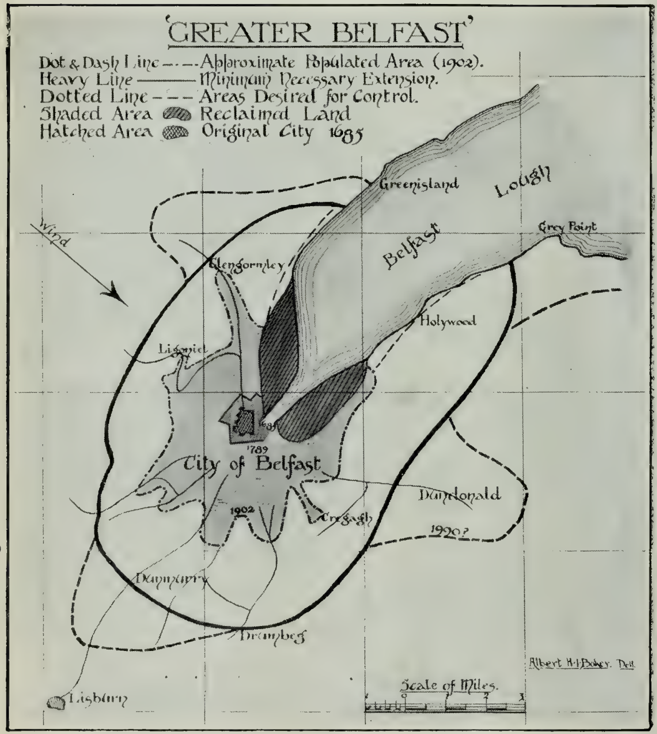
(II.)—Future.

But if it is both interesting and important to look backwards into the past of our town, it is more exciting and of much more importance to forecast the developments ahead of us, if only because, to however small an extent, we ourselves can appreciably influence it. Under God, a community can shape its own civic destinies. The Tercentenary Map of 1913 has marked upon it, roughly, the city limits one hundred years earlier, and two hundred years earlier. (Fig. 5). Can anyone look at it and doubt that further changes are coming? We see what the city has been: we see what it is: can we see what it will be? Assuming a spirit of progress and civic pride, I think we can prophecy

Fig. 6.

River Lagan. See p. 13.

FIG. 7.



GREATER BELFAST. See p. 15

some of the changes which, at any rate, ought to take place before this century closes. But for this we need an ordered scheme, a City Plan.

Of necessity it must be a many-sided Plan. It must be designed much in advance of the actual needs of the city at any given moment. It must touch the life of the community at many different points. Among its objects, it would provide for :—

(*a*) *Housing.* There is at this moment hardly a vacant house in the city. Since the collapse of the building "boom" about 1900, there has been comparatively little increase in the accommodation available either for rich or poor: yet our population has been increasing, and, (quite apart from possible further increase), there is immediate need for great numbers of new houses. But there is also reason to believe that the years immediately ahead will see a large increase in the local demand for skilled labour,—and therefore for more houses and more *good* houses. Messrs. Harland & Wolff alone have told us that they expect to be able to employ an extra 5,000 or 6,000 men: and the Harbour Commissioners have published their costly and ambitious scheme of dock extensions. Including all classes, I think it is fairly safe to say that we shall need at least 1,000 new houses per annum for the next 10 years to come, or, say, *three per day.* We have been proud of the fact that our Belfast housing conditions have been, on the average, good: and yet we must admit that they are not yet, even nearly, good enough to satisfy the ambitions of the rising generation of workers: and that, while our worst is certainly not as bad as the worst elsewhere, our best falls very far short of what other cities have recently been doing. Here, as elsewhere, artizans are going to establish for themselves, during the next twenty years, not merely a permanently higher scale of *wages* (out of which they will be able to pay a higher rent), but, a permanently higher scale of *life*: they demand, and will obtain, many opportunities for reasonable enjoyment, which will, in turn, alter their whole outlook on life, and which will disgust them with the prospect of

living permanently in endless vistas of identical brick dog-kennels, which, if they are properly connected to the town sewer, satisfy our building authorities. In a well-planned city, it would, for example, be impossible, *for it would be illegal*, to issue an elaborate scheme of harbour extensions, without including in it the essential provision for dock-labourers' dwellings, reasonably accessible, decently comfortable, and provided with such necessities as schools, playgrounds and gardens.

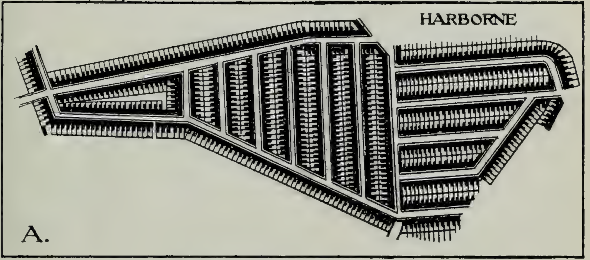
(*b*) *Schools.* There are far too few schools in Belfast. For many years we have been short by about 15,000 seats of the accommodation considered necessary for a population of equal size in, say, Birmingham or Glasgow. At least ten, probably twenty, first-rate primary schools are wanted, and are urgently wanted, now : and this quite apart from the additional schools which will be needed if our population is to expand above its present figure, and, also, quite apart from the certainty that more and better schooling is going to be demanded than has ever yet been provided. We are dealing here with the very foundations of public welfare in the future, for it is our schools which are repairing the ravages and the destruction of this war, it is in our schools that our democratic civilisation will grow, or die. If our primary schools be, as they often are, insanitary, overcrowded, insufficient in number, starved in soul or body (by underpaying teachers or skimping equipment), what sort of citizens will they turn out to govern our city in future ? For, in the years ahead, the workers are going to hold the reins of power, not only in the Imperial Cabinet and other parliamentary institutions, but in municipal government as well.

Similarly, if we need schools, we need playgrounds. The first city map I would wish to make for our Survey would be a map of the children's playgrounds. The need for them, in scores, is almost appalling. No child should have to walk more than a quarter of a mile to a playground.

Thus, a compulsory reservation for schools and playground would be one of the first essentials, in our Town Plan, in every area undergoing either new development or reconstruction.

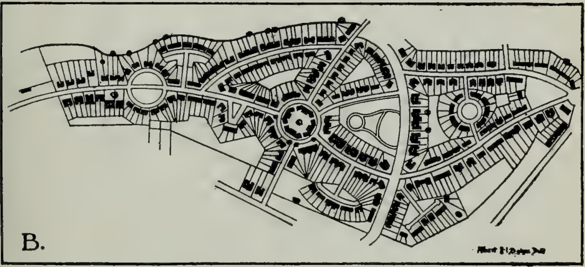
Fig. 8.

"Cities in Evolution" p. 157



THE BUILDING OF A SLUM.

"Developement" of an Estate under usual Municipal Byelaws – 40 Houses per acre.



THE SAME ESTATE.

As built over under Town Planning "Byelaws" – 10 Houses per acre.

See p. 16.

Fig. 9.

The Old Style gives place to the New.

See p. 17.

(*c*) "*Amenities*." It is an ugly word, but it stands for the preservation of all beautiful places remaining in, or close to, the city: for example, the banks of the Lagan (Fig. 6) from Ormeau out to Drumbeg. We should have absolute control of all this beautiful waterway, and should open a drive along it which would remain for ever a credit to those who had saved it from the steady destruction which it is rapidly undergoing at present. Again, our parks and public gardens are all too few and too small. Let us not starve our future city of these lungs. Such places as Orangefield, Belvoir or Stranmillis, and the pretty country around the Forth River, by Glencairn and Ballygomartin, still remain for us to utilise in the public interest. It is unnecessary to erect mediaeval fortifications upon a hill-slope in order to make it beautiful :—heather and gorse and daffodils will do this for us at a tithe of the expense. May we not have a great wild garden of such simple things on the slopes of the Cave Hill or the Black Mountain? May we not have, both as a lung and as an attraction in itself, a good botanical and agricultural garden and college out Strandtown way? Why should we not possess a small Zoo? It need not be larger than the one in Dublin, and there is plenty of room up the Lagan.

(*d*) *Churches*. We need to make further provision for the religious requirements of the city. The central premises of my own Church are but dingy and inadequate : the Methodist Church has none at all : and there is no Roman Catholic Cathedral. The historic Church of Presbyterianism in May Street is surrounded by buildings hardly less sordid than those around the Cathedral. Possibly, some part of these needs would be supplied were the War Office to decide on abandoning Victoria Barracks in favour of another suburban site like Holywood, and so release a great area for schools and playgrounds and the like. The old Lower Barrack Yard facing Great George's Street would make a fine location for a Roman Catholic Cathedral.

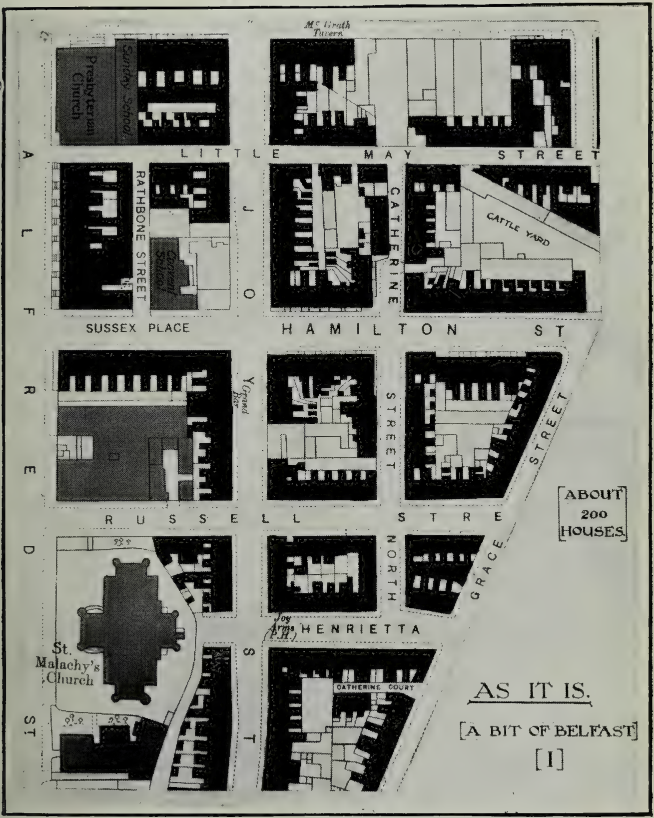
(*e*) *Traffic*—(1) *Roads*.—We have done much to improve our roads and streets for convenience of traffic,—much remains to

be done. Waring Street needs widening: if the Cathedral Mall were opened, a new street connecting the docks with the Shankill Road could easily be worked in. Great Victoria Street needs continuing at its full width down King Street and by Gresham Street to Royal Avenue. Coming down the Antrim Road, a new wide street is wanted from Carlisle Circus via Townsend Street and Durham Street to the Lisburn Road at Sandy Row. Similarly, a big route is wanted from Bloomfield across to Ormeau.

(2) *Railways.*—As regards Railway facilities, it may be that we have for ever lost our chances:—but would it not be desirable at least to have an expert re-examination into the remaining possibilities? A Central Station would be a vast convenience. It would presumably have to be located somewhere about the area between the Gas Works and the Albert Bridge,—and the nest of slums at present occupying most of that section would be a very good riddance, in any case, even if the space were to be used, not for a big Station, but only for an extension of our markets.

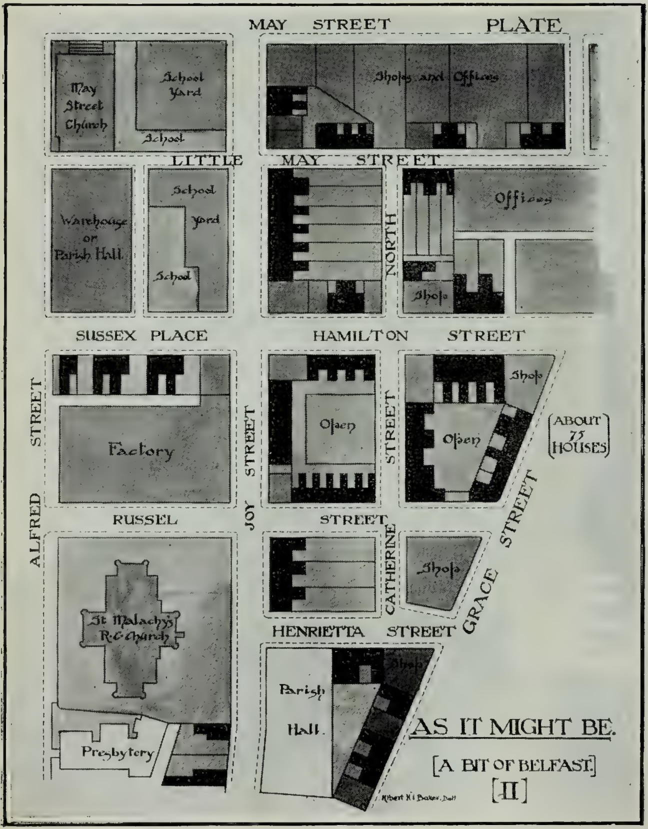
(3) *Trams.*—The tramway policy of a city is bound up in the most intimate way with its Town Plan. Our present system requires consideration in the light of future developments. For one thing, uniform fares should be established. We should deliberately continue what we have already begun, driving our lines far out into the country, on wide roads,—but we should see to it that working men and working women shall have cheap and rapid access to their work even from the furthest terminus of our public conveyance,—else the greatest of all gains from public conveyance is thrown away. How is it that we have not yet taken better advantage of the fact that hardly any city in the world has such easy access to such beautiful surroundings? Again, is it not almost time to begin a systematic linking up of the suburban tram-heads, so that we may ultimately have a full circular route? It would be easy to begin, by a link from Malone terminus across Shaw's Bridge to Ormeau terminus, and the

Fig. 10.



See p. 18.

FIG. 11.



See p. 18

extension would open up a large and beautiful district for new suburban residences.

(*f*) *Reclamation.* A glance at the Map will show that we have approximately four square miles of slob and shallows along the sea front capable of reclamation. Doubtless most of this is, so to speak, ear-marked for docks and shipyards : but, bearing in mind the direction of the prevailing wind, and the difficulties of drainage, it would seem to me that most of the new industrial enterprises which may be suggested in future should be located on the flat reclaimed lands along the Shore Road. Any that involve dirt or smoke or smell should assuredly be so limited !

(*g*) *New Boundary.* I have made a little sketch map (FIG. 7) upon which I have indicated, very roughly, four or five stages in the growth of Belfast. The little central oblong is the city of 1685, the line around it is the boundary as it was about 1789 : then comes a line which shows the present populated area : outside these lines there is a heavy black line, with heavy dotted extensions. The first of these indicates the territory which should be brought under the control of the city as soon as it is possible to do so : and the second is meant to suggest the directions in which still further growth is likely to take place. It would be a principal function of our Institute Committee to look into a whole series of questions of this sort, and to suggest when and by how much the borders of the city should be extended.

(*h*) *Government.* One cannot look at a map such as this without reflecting upon the manner of governing the community which it represents. We have at least five separate local authorities in Belfast, each of which is self-contained, and each of which acts, to all intents and purposes, independent of the other : these are the Corporation, the Harbour Board, the Water Commissioners, the Board of Guardians and the Commissioner of Police. Is it desirable that these should forever be separated into the existing watertight compartments ? Or is it reasonable to hope that the City Government may

be unified and co-ordinated to a single whole? It seems to me that the value of citizenship, and the dignity of the city, would be increased by throwing full responsibility upon a single elected body for controlling each and all of the departments of civic administration. There are many such details in the art of clean, efficient and popular government which could with advantage be studied in connection with proposals for a Greater Belfast.

SOME HOUSING NOTES.

I have dealt, in a very summary manner, with some eight or ten sections of the work which would lie before our Institute Committee. May I refer back to the first of these sections, (***Housing***), p. 11, and elaborate it a little further?

Why is it that our typical new city street is a slum-street before ever a tenant enters a house in it? Mainly because we put too many houses upon an acre. Fifty human beings, or, say, ten houses, is amply enough per inhabited acre: we are accustomed to a plan which encourages four or five times this figure. Putting it another way, if Belfast builds 5,000 new houses during the next five years, it ought to take at least 500 acres of land to accommodate them. Unless they are prevented from doing it, our present civic regulations in this matter will probably squeeze the whole 5,000 houses into about 100 acres. Then we shall have a new slum on our hands, which will cost a lot of money to pull down and reconstruct within thirty or forty years.

What is the remedy? It is twofold. (1) The new work must be done in a new way, not in accordance with the slum tradition: and (2) the old work must be gradually reconstructed.

New Housing. The best arguments I can produce are not so easily stated in words, as in maps and drawings. In FIG. 8 (A) I have shown an estate at Harborne, which the speculative builder had actually planned for "development" (save the mark!) as it is drawn. In FIG. 8 (B) is seen the same estate as it was subsequently built over for a Co-Operative Tenants' Society.

Fig. 13.

What We Had. See p. 18.

Fig. 14.

Fig. 15.

What We Have. See p. 18.

Speaking for myself, I have found that these two small plans give the key to the whole programme of Town Planning. It is clearly a damnable and inhuman thing to allow streets like (A) to be built, when, by the exercise of a little care and forethought, they may as easily be built in accordance with (B). FIG. 9 points the same moral : but illustrates it a little differently by showing the actual change in operation. The lower part of FIG. 9 is the Old Style with which we are so unhappily familiar in Belfast : the upper part is the New, which will, I trust, soon become our normal method of expansion. We should do an important piece of preliminary work if we were only to select a typical "growing edge" of Belfast, say, the top of the Old Park Road, and prepare a full set of plans and perspective drawings, showing (1) what it is, (2) what it will be if we do not insist on a change of method, and (3) what we could make it by the application of Town Planning principles.

Reconstructing Old Areas. It is much more difficult to suggest what to do with the wilderness of abominable planless little streets, where there are no "amenities" to preserve, or even, apparently, to restore. If we have, as we have, built miles of mean streets in the likeness of FIG. 8 (A), we cannot really juggle them into the likeness of FIG. 8 (B). We can, slowly, and bit by bit, reconstruct them towards a more civilised set of ideas. *But we cannot take them first. We must begin with the new houses* : when we have got the first few thousands of them built, the existing over-pressure upon the mean streets would begin to be reduced. We could then afford to take one area after another, and rearrange it as might seem best in each individual case, always bearing in mind that 10 dwelling-houses, or about 50 human beings, is sufficient for an acre of land.* Sometimes we would clear away a block of houses and make the site into a school yard or playground : sometimes we

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*If some of the land is occupied by factories or churches, then there must be a still further reduction in the density ratio.

would reserve a block or two for new warehouses, shops or factories. Sometimes we would arrange a parish hall or a cinematograph in place of an insanitary rookery. Occasionally we would find that we had too many foolish little cross-streets : then we would take two blocks at a time, pull down the central rows of houses, wall across one or both of the open ends, and leave a play ground or an allotment area in the open quadrangle. Often we could do a good deal by merely opening a space of light and air around an existing church or schoolhouse. Occasionally, we might find that the best available improvement would be simply to abolish one or two houses out of every four, leaving the sites clear for the benefit of the remainder. FIGS. 10 and 11 illustrate these suggestions : FIG. 10 being a small piece of Belfast as it actually stands to-day, and FIG. 11 the same section reconstructed, arbitrarily, to illustrate the working out of some of the above tentative suggestions* : doubtless it could very easily be still further improved. Any large-scale map of any portion of Belfast will afford equally interesting exercises in the civic imagination : the one here illustrated was chosen entirely at random.

As this is a matter which many people find it easier to understand from photographs and pictures rather than from plans, I have chosen a few characteristic examples for illustration. FIGS. 12 and 13 show very plainly what we used to be contented with : they are portions of "congested districts" which have latterly been removed. FIGS. 14 and 15 show what we are still (officially) contented with : they are *new* houses and streets quite recently erected by the municipal authorities. It is sufficient comment upon them to point to FIGS. 16 and 17 which show what we shall not be content much longer to do without : they are workers' dwellings erected at Earswick in Yorkshire. Had space and opportunity offered, these illustrative examples of

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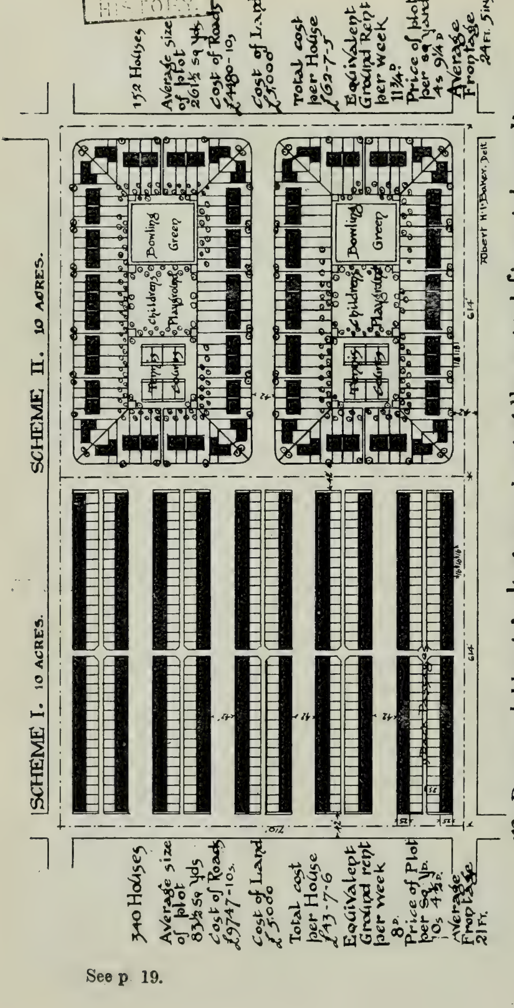
* It will come to many of us with a certain surprise that, if all this were successfully carried out, we should have merely restored our town to something like its original condition, as proved by the map of 1685 !

Fig. 16

Fig. 17.

What We Want. See p. 18.

Fig. 18.



Mr Raymond Unwin's diagram showing the actual financial results of "Garden City" development as compared with the ordinary town development.

See p. 19.

housing, good, bad and indifferent, could easily have been added to : but the principle involved is the vital point, and this principle can hardly be better stated than in Mr. Raymond Unwin's diagram, FIG. 18, in which we can read very plainly the reason why the official improvements made just before the war are so very little in advance of the slums which they replaced.

Cost. At this stage, it may well be asked, how is all this going to be paid for? Obviously, it would be a very costly business. I take it that the expense would be borne partly by the State, partly by the Municipality, partly by private enterprise. As regards the State, already a huge scheme of national Housing is afoot in Parliament, involving the erection of anything up to a million new houses. Belfast will, of course, have its share of these. As regards private enterprise, the evils we hope to cure have been so largely the result of uncontrolled private enterprise that our aim will probably be to supervise its activities and check its natural lust after cheap buildings and high rents, rather than to hand over another generation of our people to a fresh group of jerry-builders. But as regards the Municipality, there is one surprising and hopeful possibility. City development, on the lines here indicated, could, to a very large extent, be made to pay for itself, *assuming that the City will adopt a very broad and far-seeing policy.* The essential point of this policy is that the City should own, or control the ownership of, all the unoccupied building land which could possibly be utilised for thirty or forty years ahead. The manner of obtaining such ownership or control would be to buy—or take options to buy—at the official figures which are now recorded in connection with the Land Values Taxation clauses of the 1909 Budget. If necessary, compulsory powers, to acquire land and options at these prices, would not be hard to obtain from Parliament. Let the City begin to buy up its own edges and outskirts, at least 1,000 acres to start with, and let it obtain options over other portions, so large that come what may, it will never be possible for private speculators to stop or check the development

of the city by withholding land from the market for the higher values which they might obtain after a few years. Having bought a suitable strip, let the City lease it for building, under careful supervision, in accordance with the City Plan. Intelligent planning, on modern lines, will prevent waste of capital expenditure in a multitude of ways; and the public ownership of the ground will enable rents to be fixed at a figure which will not be inflated by private profiteering. Within these limitations, it seems to me that private enterprise would still have enormous scope for all the energy it is capable of exerting. In private enterprise, I include Co-Partnership groups, and Building Societies, as well as private firms and individuals.

As regards possible alternatives, direct *State* building and ownership appear to me to be out of the question: it is physically impossible for the Board of Works to do it, and I have not the least expectation that Parliament intends to do anything of the sort. *Municipal* building and ownership of the actual houses themselves might appear more likely, but here again, I do not believe that our Corporation is likely at present to take over the building trade of the city as a going concern and run it from Donegall Square,—as well as a big rent-agency department. The plan which has been officially adumbrated seems to be for the State to lend very large sums of money to local authorities at a low rate of interest; and that, in turn, local authorities should lend the same money to large numbers of property owners. I have only this comment: unless the State insists upon a proper city plan, properly supervised, upon the general lines indicated in this essay, we are likely to find that, after the lapse of a few years, (1) the property-owners have got most of the cash, (2) the city owns neither the land nor the houses, and (3) the tenants are paying high rents for houses little if anything better than they are occupying to-day.

My claim has been that, to a very large extent, we could make city development pay for itself. But it is only fair to my own suggestions to observe that there must necessarily be some

portions of a broad scheme that, taken separately, could not be, directly, a paying proposition in the strictly financial sense. No amount of financial genius will extract a profit-rent out of a child's allotment garden! But surely, this War has taught us that "money" and "wealth" are not identical terms? Shall citizens of Belfast not learn to take more of their municipal dividend in terms of health and happiness for our youngsters, in opportunities for activity in mind and body for people who have nothing to-day outside the narrow grind of their working lives? God knows, the world has paid enough since August, 1914, for pure destruction, in order that life and freedom may be preserved: may we not, as part of our War Memorial, spend a small fraction more upon construction, so that, in our own times, we may see the growth and liberty again at work?

CONCLUSION.

Our War Memorial shall thus be no mere carven stone upon a pedestal: it shall be at once a tribute and an inspiration: a tribute to those who have fought for our freedom, and an inspiration to us to use our freedom to nobler ends. It may be that, in days far ahead, men shall learn here of the Great War, not as we have learned of past wars in our school-books, but by themselves living in the realization of our War Memorial ideas.

Is this too much to hope for? Rather may we not say that we shall not have justified all the heroism of our men these four years past, if we do not see to it that these dreams shall begin to come true, in our own day, and by our own effort? The gallantry of Thiepval has already given to July 1st a new significance, a new historic orientation. Shall we not also give a new meaning to our old city motto—*Pro Tanto Quid Retribuamus*? "For so much, what shall we give in return?" What shall we give? I say we shall give to them and to their children a new city, a new hope for the days to come.

BELFAST

NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.

PROCEEDINGS,

SESSION 1918-1919.

No. 2.

BALLYMARTIN CHURCH RUINS

AND

THE RATH OF DREEN.

BY MR. H. C. LAWLOR, M.R.I.A.

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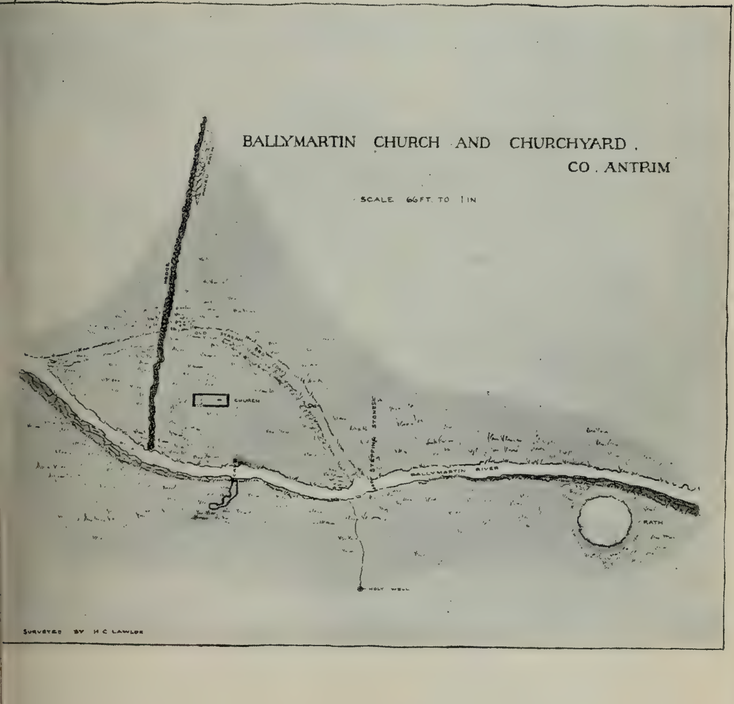
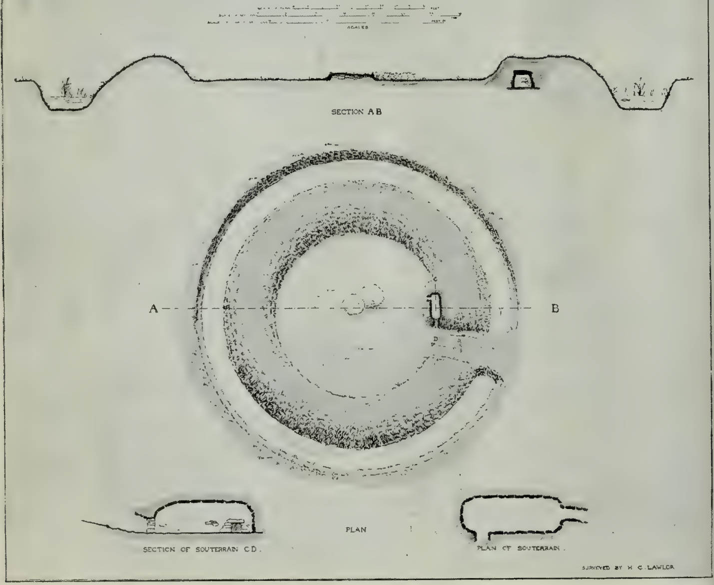
1919.



BALLYMARTIN CHURCH AND CHURCHYARD.
CO. ANTRIM
SCALE 66 FT. TO 1 IN
HEDGE
OLD STREAM BED (DRY)
CHURCH
STEPPING STONES
BALLYMARTIN RIVER
RATH
HOLY WELL
SURVEYED BY H C LAWLOR

THE RATH AT DREEN NEAR CULLYBACKEY.



BALLYMARTIN CHURCH RUINS, AND THE RATH OF DREEN.

Papers read on the 10th December, 1918, at the Annual Meeting of the Archæological Section,

By Mr. H. C. Lawlor, M.R.I.A.

BALLYMARTIN CHURCH RUINS.

The ancient Church and Churchyard of Ballymartin lie in a picturesque little glen on the north side of the Ballymartin river exactly a mile and a quarter east of Templepatrick (see O.S. Map, sheet 51). The Church, the orientation of which is nearly due east and west, is about 30 yards from the stream, on a slightly raised knoll, while on the east, north and west can be traced a now grass grown, but marshy channel, which shows that it was once an island church. It is rectangular, measuring internally 51 by 17 feet. In the immediate neighbourhood are several objects of archaeological interest. Leading due north from what was once the little lakelet in which the island stood, is an ancient paved road traceable for several hundred yards until it is lost in a plantation. Just above where the stream once widened out into the lakelet is an old ford or row of stepping stones, at a short distance from which on the south side of the river is an ancient well, at one time a Holy Well.* Opposite the Church on the other side of the river is the entrance to the Souterrain, the investigation of which is described in the Report of this Society for 1917. 170 yards east of the cave, surmounting a steep cliff overhanging the river, is a small rath much obliterated by tillage. The churchyard lies south and east of the church,

* For traditions respecting this well, see Ordnance Survey memoirs quoted in O'Laverty's Down and Connor, Vol. III., pp. 17-18.

and contains many rugged graves, some of which are marked by rough uninscribed stones. The site of the church and churchyard has never been tilled, but the remains of the walls were barely distinguishable, being overgrown with grass and brambles.

The investigation of this ruin was carried out at various dates during the summer of 1917, as opportunity and weather permitted, and in all some 10 days were spent on the work. I had the assistance of two steady labouring men, and during the progress of the investigation it was visited by Professor Macalister, Mr. Andrew Robinson, of the Board of Works, Canon Carmody and Mr. R. M. Young, whose valuable advice and information I wish to acknowledge.

Our first undertaking was to clear out the whole interior of the church, which was filled to a depth of from two to five feet with the fallen debris of the walls. The removal of this brought us down to the original floor level, which was covered with the remains of burned matter, and at the same time exposed the types of the masonry of what still remains of the walls. The original stone work apparently had not been built in sunk trenches, as the foundations were on the level of the charred surface of the earth floor. The masonry itself was of two distinct types, dry or clay built and mortar built. In removing the debris, all stones showing cutting were carefully laid to one side and will be described separately.

We worked down from the eastern gable, lifting the stones and debris to the outside. About nine feet from the gable was a large recumbent pillar stone about 4 feet long, lying east and west and equidistant from the side walls. It was impossible to tell whether this stone was originally partly sunk in the floor or lying on the surface or erect. Beneath it we found in the soil two skeletons buried in a sitting position facing east.

As we proceeded westward we found human bones at various depths in the debris, showing that interments had taken place long after the church had become a ruin.

At the extreme west end under the last of the debris we

found a deep deposit of what is usually described as of the kitchen midden type. It consisted of wood fire remains containing numerous bones of animals and broken pottery. There were also human bones in places, evidently the remains of one or more bodies that had been interred at a period much later than the date of the kitchen midden. We also found one stone of a large quern here. The midden remains were from 6 to 18 inches deep, and extended considerably below the level of the bottom of the foundations of the wall and the floor level of the Church, but not under the wall; they were piled against the inside of the wall, thus proving that they were deposited subsequent to the building.

The masonry of the walls is to a considerable extent dry built, with earth between the stones, indicating a very early date. It is very dangerous to come to dogmatic conclusions as to the age of early stone built churches. Petrie discusses the subject very fully in his "Ecclesiastical Architecture of Ireland Anterior to the Anglo Norman Invasion," and O'Hanlon, in his "Life of St. Malachy," refers to the matter in some detail without arriving at any definite conclusion. Generally speaking, I think it may be assumed that, except in the larger and more important ecclesiastical centres, the great majority of churches in Ireland prior to the tenth or eleventh century were wooden structures. If we assign the original date of Ballymartin stone church approximately to the tenth century, we are probably fairly correct. That it was the successor of a more ancient church or even pagan place of worship is not improbable from the discovery of the two bodies buried, facing east, in a sitting position, under the pillar stone. From the crudeness of some of the pottery found in the priest's kitchen, I can hardly think the date of the stone church can be very much later than the approximate date I suggest.

Many of the stones show evidence of having endured extreme heat, while the charred remains over the floor level prove that the church was, at least once, burned. The absence of any sign of fragments of slates or tiles proves that it was roofed with

thatch. Of the carved stones, some were rough hewn basalt, while a number were of smooth magnesian limestone, of which so much was used by the Normans in the building of the churches of St. Nicholas, Carrickfergus, and the old church at Holywood, and taken from a now exhausted quarry at Cultra.

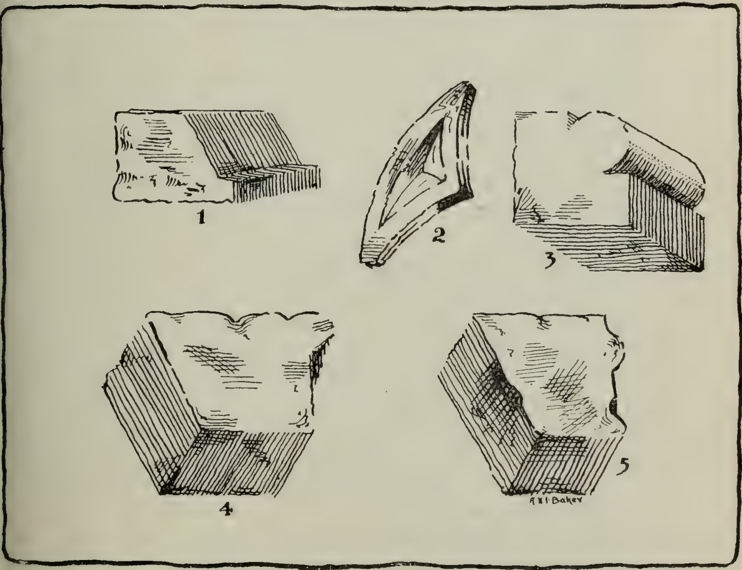
The basalt carvings were all fire marked, while the limestone were not, from which it may be assumed that the ancient native Irish Church was burned, and that it was restored and partly built during the Norman occupation. It was probably at this restoration the walls were patched and partly rebuilt with mortared masonry, and the limestone jambs inset. The western end of the south wall, for about twelve feet from its junction with the gable, was entirely gone, but there was one stone in position where the remaining portion of this wall terminates, which was evidently the bottom stone of the east jamb of the entrance door ; the Ordnance Survey memoir referred to above and quoted by O'Laverty, mentions that the door was in the north wall, but this is quite wrong, as no gap occurs in any part of the walls except at the western end of the south wall.

The accompanying rough sketches show examples of the only carved stones found ; they all appear to be portions of the jambs and mullions of windows, but no fragments of glass were found in the excavations.

Of the considerable deposit of kitchen midden remains found at the west end of the church floor, a detailed account may be given. The half quern of Scrabo freestone was practically perfect, measuring 18″ in diameter. Of the other half we found two fragments among the debris of building material, but not in the kitchen midden remains ; they were of Tardree rhyolite. I assume that the two fragments were of the half quern that had been originally mated with the other half found in the kitchen midden, but of course there is no proof of this.

The pottery remains are of much interest. There were not found sufficient fragments of any one vessel to effect reconstruction. There appear to be pieces of six vessels, four show

ornamentation by scores or dents, one, a thin unsooted vessel, evidently a milk bowl, had a smoothing surface paste, and one was wheel turned, and elaborately ornamented both inside the lip and outside. The last mentioned is of particular interest owing to its minute resemblance to portions of a vessel found in 1897 by Mr. R. M. Young, in a sandhill settlement near Groomsport*



1 and 2—Scrabo freestone, not apparently damaged by fire.
3 and 4—Basalt, much burned there were several examples of 4.
5—Cultra Limestone, undamaged by fire, there were several of these, and one base of a small window of same.

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* Illustrated and described in the Ulster Journal of Archaeology, 2nd series, vol. iv., p. 46.

and also to a portion of a vessel found in the Rath of Dreen, Parish of Ahoghill, in our investigations this year, to which I will refer in a subsequent paper. The exact resemblance of these three vessels to each other in shape, decoration, finish and material seems sufficient to prove that they are approximately contemporaneous. The finding of fragments of a pot of this particular pattern within a church building of about the tenth century confirms the conclusion arrived at with regard to the date of the pottery of this precise type, in my papers on prehistoric dwelling places in the Reports of this Society for 1916 and 1917. We found one piece of pottery, evidently the bottom of a vessel, showing signs of glaze of mediaeval type, but unfortunately I cannot be certain where exactly it was found. I thought at first these kitchen midden remains were those left by the original artizans who built the church, but Professor Macalister informs me that many instances have been noted in early churches where the priest lived in the west end of the church, and that this is an example of a priest's kitchen.

Of the history of Ballymartin Church we have practically no certain knowledge. The reference to "the church of the old town" in the taxation roll of 1307, as Dr. Reeves thought, applies to it; no other mention of it appears in any available record until about 1600, when it is referred to as "the church of Ballymartin in ruin."*

From various sources we know that for over a century after the wars of John de Courcy, the Normans were firmly settled in Co. Antrim, but especially in the fertile district, now known as the valley of the Six mile Water, but anciently as the Tuath of Magh Linn or Moylinne. Prior to the Norman invasion much of this territory was the home of the clan O'Flynn. When the Norman occupation was effected, it was parcelled out among the followers of De Courcy. The Savages obtained the lands round Donegore and Rathmore, the townland of Ballysavage perpetuating

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* See Reeves, Ecclesiastical Antiquities, p. 66.

their memory. The Mandevilles held sway east of Templepatrick, while the Logans were settled in a large territory with the present Ballyclare as its centre.

The names of a few modern townlands and parishes seem to be all that remain to us of the Norman conquest of this part of Ulster. After the desolation of all this district by Edward Bruce between 1315 and 1318, and the internal dissentions culminating in the murder of the Earl of Ulster in 1333 by the Logan faction, the O'Neills found the conquest of central and south Antrim and north Down an easy matter; by 1360 they had practically subdued or driven out the native O'Flynns of Ui Tuirtri, whom the Normans appear to have allowed to remain in possession of a portion of their lands, and during the century and a half that followed, all the Norman settlers in the southern half of Co. Antrim, excepting Carrickfergus, and in north Down, were similarly dispersed or exterminated. Ballymartin, with Ballysavage, Ballyrobert, Ballywalter and a few other townlands, granges and parishes, perpetuate in their names heroes of the Norman occupation. Ballymartin derives from Martin de Mandeville, who flourished about the end of the 13th century; Ballysavage from one of the Savages, what particular member of the family we cannot say; but the Savages were one of the most important of the Co. Antrim Norman settlers. Ballyrobert perpetuates the memory of Robert de Logan, a contemporary of Martin de Mandeville; Ballywalter was once known as Walter de Logan's town, or Loganstown, otherwise Vill de Walter de Logan. Walter de Logan was also a contemporary of Martin de Mandeville and Robert de Logan, and it is reasonable to assume that these and other townland names of Norman derivation date from a general adjustment of the earldom of Ulster carried out by the great Richard de Burgh, Earl of Ulster, about the year 1305*. It is

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* See Orpen, "The Earldom of Ulster," Journals of the R S.A.I., vol. xliii., pp. 30—46, and 133—143, and xlv., pp. 123—142.

interesting to note that of all the great Norman families settled in County Antrim after the wars of de Courcy only one withstood the reconquest by the Irish O'Neills, and the later English and Scottish Chichesters, Hamiltons, and other Elizabethan adventurers: I refer to the grant of the Glynns to the Bissets. They, through their descendants, the MacDonnells, still remain, Earls of Antrim, in the proud position of the only Co. Antrim family of the Norman conquest of Ulster surviving in their original lands.

THE RATH OF DREEN, PARISH OF AHOGHILL.

The townland of Dreen (the blackthorn) lies between the villages of Cullybackey and Ahoghill, the Rath being one mile S.S.W. of the former, but in the Parish of the latter name.

The Rath where our investigations took place may be seen on the O.S. 6″ Map, Sheet 32, a little to the left of a point $1\frac{3}{4}$ inches due south of the letter "C" in the townland named Cardonaghy. There is another Rath a few hundred yards to the east of that of Dreen, but it is in the townland of Cardonaghy.

The Rath of Dreen is of the usual shape, but rather larger than the majority, the airlis or flat enclosure being 110 feet in diameter. The circular vallum is built of the soil extracted from the surrounding trench, and the height from the bottom of the trench to the top of the vallum is about 17 feet. The airlis is not raised above the level of the surrounding fields. As is usually the case the Rath is built on a slight slope, which facilitated the drainage of the enclosed dwellings.

Almost in the centre of the airlis, outlined in the grass were traceable two contiguous circular hut sites, each about 15 feet in diameter, slightly raised above the level of the immediately surrounding ground ; to the east up against the inner side of the vallum is a cloghan, or earth house of one chamber as shown in

the plan. This is built in the style of the ordinary souterrain, but is almost completely above the ground level, with soil heaped over it, a rather unusual form of construction. At some time a gap was made in the vallum on the east side, and the soil thereby removed was thrown into the trench to make an easy entrance for cattle. I fancy that in doing this a second chamber of the earth house was destroyed, as the foundation of the eastern side wall seems to extend somewhat in that direction. The proprietor of the farm, Mr. W. J. Kernoghan, gave his consent to, and otherwise assisted in the investigation of the Rath, and we spent Easter Monday and the two following days at the work, with five men.

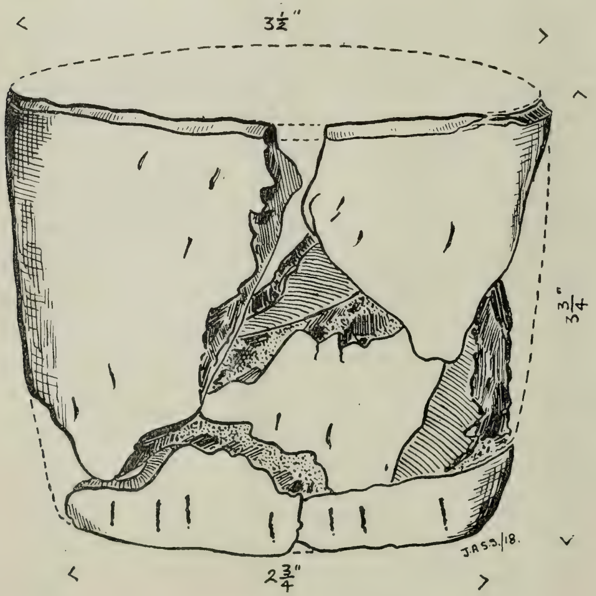
We first dug a trench round the outside of the vallum in the hope of finding the midden where refuse might have been thrown out from the dwellings inside. The depth of the peaty mud however we found to be from four to five feet, and as we dug, water gathered in the excavations, compelling us to abandon the search in the trench.

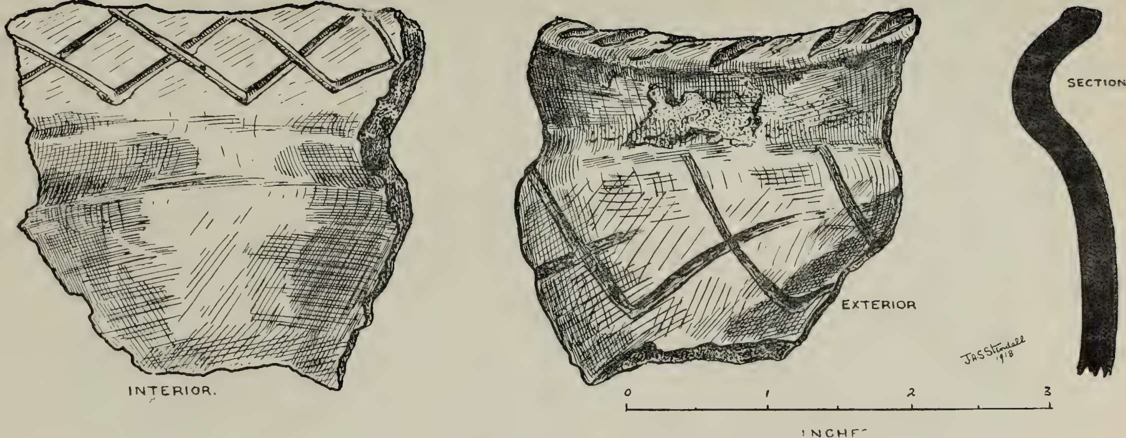
We then put some of the men to remove the sods carefully from the hut sites, while the others dug trenches at regular intervals over the airlis. Except at one spot near the southern end of the gap, where we found some coarse pottery, all the archaeological remains were found in the hut sites.

In these, immediately beneath the sods, the earth was black and sooty, containing numerous fragments of burned sticks and bones of animals, a few pieces of iron, too corroded to enable us to form any idea of their purpose, three stone axes and a considerable number of fragments of pottery. All were lying on or between a fairly regularly constructed series of hearths made with ordinary large flat-topped field stones. A few fragments of flint were turned up, but none of these seemed to belong to even the crude type of implement generally described as "worked flints." The utility of the iron fragments being so hopelessly unrecognisable, we are confined to the pottery and the stone axes in our theoretical deductions as to the age of the hut sites.

The greater part of the pottery was of the crude class to which in former papers I have given the name "Souterrain type," purely hand made, without ornamentation, not made on the potters' wheel, not finished with any surface paste, but evidently baked in intense heat, and differing in this respect from the cinenary urn or bronze age pottery, which displays less evidence of fusion by great heat.

There were fragments of a large number of different vessels, but out of the whole collection we were only able to reconstruct, almost completely, one, and partially another. Both of these were in the loose black soil of the hut sites. The first of these is a cup or tumbler, without any sign of soot; it is crudely

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ornamented by the potter with dents made by his finger or thumb nails. It is circular, but not wheel-turned, and measures $3\frac{1}{2}'' \times 3\frac{3}{4}''$. The other vessel is a cooking pot, and is heavily sooted inside and outside. It is wheel-turned and bears a remarkable resemblance in shape, decoration and material to Mr. Young's find in the Sandhill near Groomsport, and the fragments already described as having been found in the priest's kitchen of Ballymartin Church. These three pots are so similar in general form and in every important detail, that one is compelled to conclude that they are approximately of the same period.

From deductions arrived at with regard to pottery in my papers on pre-historic Dwelling Places of Man, in the reports of the Society for 1916 and 1917, I placed the date of this class of of vessel later than that of the Souterrain type, probably the 9th to the 11th century. The finding of a portion of an almost exactly similar vessel in Ballymartin Church Priest's kitchen curiously confirms the deductions arrived at in these articles.

The deposit of refuse, etc., on the hut sides was not at all deep, perhaps ten or twelve inches, including the hearth stones. From this we must conclude either that the house refuse was systematically cleared away by the dwellers, or that the place had not been occupied as a dwelling for a long period. In many lake dwellings hearth sites are found superimposed one upon another, in layers representing many successive periods, showing long continuous occupation ; this was not the case here however, and while some of the coarse pottery was found down on the hard till and round the bottom of the stones, most of it was in the soft upper level of the black soil. This applies in particular to the drinking cup, the wheel turned pot, the three stone axes, and the iron fragments, which were all found within a radius of a few feet, about the centre of the western hut side. We must conclude that all these articles were in use by the last occupiers of the hut.

It will doubtless be said that this is impossible, and that

stone axes could not belong to the late iron age settlement ; but facts are before us. In this connection I may recall that in two of our excavations recorded in detail in the Reports of this Society for the years 1916 and 1917, stone axes were found in immediate association with late iron age remains. I refer to one found in the souterrain at Donegore, and two, of which one was quite perfect and the other a fragment, found in the Ballykennedy Iron Foundry remains. They are illustrated and described in the Report for 1916. Of the three found together at the Rath of Dreen, a detailed description may be of interest.

No. 1 is a stone axe of the small thick oval section type. When left by the hut dwellers where we subsequently found it, it had ceased to be of use for its original purpose ; the cutting edge is completely worn or chipped away, but the top end bears unmistakable evidence of its having descended to the purpose of an ordinary hammer. The difference of the appearance of the chipped surface of the cutting end and the top is very marked, and may represent a difference in age of an indefinite period. This axe, though in use by the hut dwellers as a hammer, may have been, as an axe, hundreds of years old at the time.

Not so, I think, Nos. 2 and 3. They are both of the thin flattish type which some theorists regard as the predecessors of copper and bronze axes of similar shape and the models on which they were designed ; they believe therefore that they are what they call late stone or early Bronze Age, say 1800 to 1000 B.C. No. 2 has a few small chips off the cutting edge. No. 3 is absolutely perfect and presumably unused, as was the very simillar axe found at Ballykennedy. It is probable therefore that No. 2 is the axe which was in actual use when hut dwellers left the hut, and No. 3 a spare tool in reserve.

In a recent very interesting paper by Mr. E. C. R. Armstrong, in the Proceedings of the Royal Irish Academy, dealing with "Associated finds of stone celts in Ireland" he deals with a great number of Stone Celts found at various times and places in groups of two or more, now in the Academy's Museum. It is


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nothing short of calamitous that in not a single instance that I can find has any record been preserved by the past curators as to the actual associations and surroundings in which the axes were found. "Found in a lake," "in a bog," "in a field whilst digging" are examples of all the information now forthcoming.

In the now considerable number of excavations carried out by this Society during the past four years, I have endeavoured to chronicle in the most minute detail every material fact in connection with the excavation and the circumstances and positions in which remains were found. Without such details, any mere collection of specimens of prehistoric implements is robbed of much of its instructive value ; and consequently the deductions arrived at from their inspection are liable to error.

We have now three instances in which we have found stone axes in actual and contemporary association with what are generally known as the late Iron Age remains. These are :—

1st. The Donegore souterrain, where one stone axe was found of the rather rough thick type ; Wilde in his Catalogue of the Museum of the Royal Irish Academy records the reported find in apparently the same cave of another axe and some arrow heads "now lost, and a portion of a vessel richly ornamented with inscribed scoring, now in the Academy's collection" ; he does not say, however, whether the vessel is a cooking pot or not, or if turned on a wheel ; I regret I have not yet had an opportunity of inspecting this in the Museum. Our finds in the Donegore souterrain have been recorded in the Report for 1916, and I have endeavoured to show that the age of the building of these dwellings was between the 6th and the 8th centuries.

2nd. The Ballykennedy Foundry where one perfect and one fragmentary axe were found among the remains of many articles of iron and glass.*

* In my account of this investigation in the 1916 Report I mentioned a piece of Bronze slag found close to a small crucible, which seemed to fit it ; subsequent examination proves that what from its greenness I took to be bronze slag is actually impure glass, which if purified, is the same type of glass of which the dumb-bell bead found close by consists.

3. The Rath of Dreen just described, where three axes were found, apparently just as left by the last occupier of the hut.

These three finds of stone axes in close association with Iron age remains seems strongly to suggest that these implements continued to be both manufactured and used to a very much later date than that usually assigned to them.

We concluded our excavations by clearing out the floor of the earth house or cloghan. This search was quite unproductive of results, no fragments of pottery or even charcoal being found.

I have to thank Mr. Sidney Stendall for his admirable etchings of the pottery and stone axes.

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11th March, 1919.

TREES—THE CHARACTERS, STRUCTURE AND PROPERTIES OF WOOD

WITH NOTES ON

FORESTRY AND AFFORESTATION,

BY ARTHUR DEANE,

CURATOR, BELFAST MUNICIPAL MUSEUM.

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1919.

Photo: R. J. Welch, M.R.I.A.

Scots Pine stumps on Bog in North Antrim. The trees flourished during a dry period, and were eventually killed and replaced by a fresh growth of vegetation. Page 38.

11th March, 1919.

TREES—THE CHARACTERS, STRUCTURE, AND PROPERTIES OF WOOD, WITH NOTES ON FORESTRY AND AFFORESTATION.

Illustrated by Specimens and Lantern Slides.

By Arthur Deane,
Curator, Belfast Municipal Museum.

(*Abstract.*)

One of the many things the war has done for us is to raise our regard for timber. Its cheapness and plentifulness in past years rather blinded us to its value. It has taken the war with its resultant forest destruction and transport problems to open our eyes to the necessity of considering our timber supply in the future in a very different manner from what we have done in the past.

In 1913 Russia supplied us with almost half our total imports of timber, followed by supplies from Sweden, France, and Canada, and there will be a great demand for timber from the allies for reconstruction purposes, while our enemies will have an accumulated timber wealth. We are not likely to return to pre-war conditions, and we cannot afford to rely upon the possible excess of timber from foreign countries for our industries. In Ireland alone there will be an increased consumption of timber for many years to come, and yet there is no reason why the country should not, in the future, be largely self-supporting in this direction, even if new wood using industries spring up, which is probable if areas become afforested. But if forestry in Ireland is to be successful, it must, from the initial stages, be attempted on sound business and scientific principles with a long look ahead policy, and approached with such patriotism that the generations

to come will never have to rely on foreign timber for structural purposes.

Afforestation in the United Kingdom is no new idea. It was advocated for many years before the war by pioneers in forestry like Sir Wm. Schlich, the late Prof. W. R. Fisher, Mr. A. C. Forbes, and many others. Had they been listened to, British Forests would have been producing to-day a much larger yield. We are fortunate in having in Ireland under the Department of Agriculture, Mr. Forbes, who was a Member of the Forestry Sub-Committee appointed by the Ministry of Reconstruction. Just before the war the total yield in the United Kingdom was less than 15 cubic feet per acre per annum, but under a proper forest policy it would have yielded about three times that amount. This small percentage in British woodlands is partly due to their being too open and the soil covered with injurious surface growth, and if these woodlands are to yield a greater return and a better product in a shorter time, they must, like the continental forests, be placed under proper scientific planning and economic management and not left to Nature.

Arboriculture is the art of growing trees singly, or in groups, to preserve them for aesthetic purposes; direct financial gain is not considered. Apart from their ornamental effect, trees make the air fitter to breathe by taking from it the impure carbon dioxide and increasing the supply of oxygen, and for this reason they should be planted more than they are in congested neighbourhoods of towns. Many of our city trees show signs of having been placed on a very meagre ration, which does not agree with them. The very tips of tree roots are in direct communication with the uppermost leaves of the foliage, and if roots do not get sufficient air to breathe, they cannot perform their proper functions and lead a healthy life. They need, too, an occasional pick-me-up in the form of nitrate, potash, and phosphate, especially the first-named, for they have not the fallen leaves to keep the soil in condition as in a forest. Many of them badly need serious surgical operations, which should be performed

during the autumn and winter months, so that the antiseptic applied may soak into the wounds, this it fails to do if applied in spring or summer.

Sylviculture deals with the growth of trees in dense masses in order to produce timber of high technical quality for knotty or crooked trees cannot produce good timber. The trained forester knows that tall cylindrical trees, comparatively free from knots, can only be obtained in dense forests. Under such a condition the lower branches are prevented from thriving, and so the size and number of knots are reduced when the timber is cut into boards. It is the dense type of woods we want to see in Ireland, not the open woods for sporting purposes as in the past. Sometimes trees are grown in pure forests, consisting of one species only, or in mixed woods of two or more species which is more complex. Although trees must have a certain amount of light, they differ in their requirements. The forester takes advantage of this, and divides trees into light-demanding species and shade-bearing species, and mixes accordingly, as for instance, Oak with Beech, Larch with Beech or Silver Fir, Scots Pine with Spruce, according to the soil and climate. Mixed woods should always contain shade-bearing species which protect the soil and kill out weeds; especially is this necessary on thin exposed or peaty soils, or places swept by winds. It is interesting to note that those trees having a smooth thin bark are usually shade enduring species, as is the case with Beech, Hornbeam, Spruce, and Silver Fir, while those species that early in life acquire a rough bark are usually light demanding, such as Oak, Pine, Ash, Sycamore, Poplar, Alder, and Willows.

The great difference between the Ireland of to-day and the Ireland before the Christian era lies in the amount of forest. Although good progress has been made in afforestation in Ireland under the Department of Agriculture, she is, comparatively speaking, a woodless country now, and yet, Ireland is by nature an ideal country and well adapted with her temperate and humid climate for growing timber trees. Instead of producing

the highest percentage for Europe as she should, she produces the smallest. Her hillsides become denuded by water carrying away a rich burden of soil, choking up rivers and, in some places, making the lowland soil so boggy as to be unsuitable for agriculture. Where bogs have encroached, after cutting the turf, the stumps of ancient trees are sometimes found in situ standing like small monuments as if to remind us that Ireland was formerly full of timber (see frontispiece). In fact, we have shown in such a bog an excellent example that where a forest had existed and had not been replaced, a change to an inferior soil and climate resulted. It is for this reason that we must not suppose that these tree-remains give us an indication as to what trees should now be grown upon such sites.

Before a peat bog can be made to support tree growth, it must be drained, and especially should this be done with live peat in order to destroy the surface vegetation. The fibrous covering must also be completely broken up, or better, removed for a depth of 3 or 4 feet so that the roots may dip into the soil and the new surface weathered. On such a site one would not expect to grow large timber, but poles for fencing and pit props.

Soil should be regarded as the greatest natural economic endowment of a country; it is the primary source of wealth. Our very existence depends upon it and yet the loss of soil capital by water attrition is enormous. Why should this perpetual waste of soil from hillsides go on when there is such a demand for softwoods which will grow in Ireland and yield a quick and profitable return if carried out on a large scale? On better soils trees such as Oak, Ash and Chestnut might be grown. Trees are soil builders and soil binders. Their root range is far and wide, and they act as wedges cleaving the rocky substratum into the hollows of which water percolates, carrying with it the soil particles. The fallen leaves would create a modification in the soil, which would be shaded and protected from wind, sun, and surface growth by the continuous canopy formed by

the foliage of the trees. The importance of maintaining a dense canopy above and a suitable forest floor below cannot be too strongly insisted upon. A constant moisture is kept up by rainfall, the humus, acting like a sponge, absorbs the water which gradually percolates to lower levels, to be afterwards drawn upon if required by the roots, while the surplus emerges as an even flow into the streams and rivers, freed to a large extent from its fertile suspended matter. It is on this principle that many Municipalities afforest portions of the catchment areas of their water supply.

There is no need to grow timber trees on soils suitable for agriculture, but there is no reason why vacant land found suitable for timber crops should be lying idle: it should be put to work. Mountain sides, rocky and thin soiled, up to an elevation of 1,000 feet should be planted chiefly with softwoods. Perpetual winds, day and night, high up on mountains, put a limit to the growth of trees. In such exposed situations the wind causes the upper shoots to become wind pruned owing to too rapid a transpiration, with the result that the juicy shoots wither and fall off, causing the trees to assume a stunted appearance. It is partly due to transpiration that many trees shed their leaves in winter, while some actually shed their twigs, provision being made beforehand to heal the wounds: Oaks, Poplars, Willows, Elms, Horsechestnut, are examples.

There are many problems which would have to be faced in afforesting Ireland. Transport would have to be considered as it is essential that timber should be put on the market as cheaply as possible. Rail carriage for round timber would be costly owing to the demand for other goods, and this is likely to increase with agricultural development. The demand for the supply of timber for packing cases, crates, etc., is likely to be enormous; quick transit of food to the consumer is imperative, but timber transport, although it must be at a cheap rate, unlike perishable goods, need not as a rule be urgent. Hence, consideration should be given to the old canal system which prospered

in Ireland in the 18th century before railways were built. Our canal system has fallen largely into disuse and would need to be put in order while other canals should be made. Making new canals would help to drain much bogland, and in this way a good deal of land might be reclaimed and made fertile. By means of a proper water carriage system, Ireland could in the future transport timber, at a cheap rate, for home consumption.

Forests provide employment in rural districts. They therefore contribute to the prosperity of the people, besides having a good influence upon the social well-being of the rural population, so lessening the desire to migrate to towns. Forests are good friends to the farmer. They give him pleasant home surroundings; provide him with timber near at hand for his buildings and implements; protect his land from erosion and flooding; and, as shelter belts, the trees afford beneficial effect against winds and storms for his stock and crop.

Agriculture gives a quick return, but with forests there is a long delay, and the policy should be arranged for a continuous supply. The quickest return in forestry is provided by osier beds, and where land exists upon farms too swampy for meadows, farmers would do well to transform them into osier beds to replace the decreased imports of osier rods and basket-ware caused by the war, while the tree willow, *Salix cœurlea* should be grown along rivers valleys and ditches to produce wood for cricket bats. During the war there has been great demand for willow wood for the manufacture of artificial limbs. Rocky, or poor dry waste lands should be turned into wood plots, if only to prevent barren areas being a menace to the rest of the farm. No farmer can afford to have unprofitable land any more than he can afford to keep as "boarders" unprofitable cows.

One must not forget the good work which has been accomplished by private enterprise, especially in Scottish woodlands, yet, if forests are to be given the indefinite preservation that is necessary, afforestation can be better handled by the State Forests must be regarded as a community asset,

and if public funds are to be used for afforestation in Ireland, it is essential that trained men should be provided and their knowledge put to good account Foresters are not empiricists, as some people imagine, but trained professional men. The user of timber little realises how much even the mechanical properties of wood depend upon the control of forests by the well trained forester. He must be trained in various sciences which make up what is really a forestry science. He must be a geologist and soil physicist in order to have some idea as to the sites most suitable for the different tree crops, preventing, for instance, ill adapted species on poor sites. Errors in field crops may be righted in a year, but mistakes made in forest planting or sowing may mean the loss of many years before they can be remedied. He must study forest organization, be able to prepare working plans of forest management and understand thinning. He must look upon the forest as a living community which will respond to his care, for by abuse the forest may even vanish. He must be a plant pathologist and entomologist in order to deal with fungi and insect attacks and the best means of combating them, and to do this he must understand the structure and functions of healthy trees, and the physical and structural qualities of their wood. He must be able to identify those animals, especially birds, that are useful, and those that are injurious. He must, in short, be a man with good business capacity, and a naturalist, while he must not let one trait overshadow the other.

Every facility in Ireland should be offered to men of talent to train as foresters and agriculturists. Money should no longer be a barrier for those who desire to study, and there should be a greater co-operation between the Universities and the schools, with special facilities for research and experiment in any subject of importance to forestry, both in the field and in the laboratory.

THE TIMBER.

Commercially, timbers are divided into "softwoods" and "hardwoods," but this does not, by any means, represent a scientific classification. Foresters also roughly divide trees into needle-leaved trees (or *Conifers*) and broad-leaved trees. To the former belong the softwoods of commerce—Pines, Firs, and Larches, while the broad-leaved trees include the hardwoods—Oaks, Elms, and Chestnuts, although some timbers in the latter group might be described as softwood, such as the Poplar, Willow, Lime, and Horsechestnut.

Length and Diameter Growth.

Once formed wood never lengthens, and a trunk or shoot grows in length, only at its extremity, by means of a bud, and then only during the growing season in which it is formed; but a trunk or shoot increases in girth by the annual increment of a cylinder or wood, or to be more accurate, by the addition of a hollow cone which is deposited on top of that produced in the previous year to form a compact mass, appearing on the cross cut end as rings. A nail or a spike driven into a trunk used as a fence post will never be higher up, but such objects will in time become covered by the increased diameter due to the additional layers of wood.

Parts of the Trunk.

Cambium.—This is a generative layer and is situated between the outermost or youngest layer of wood and the living bark (*bast*). It is not only important in forming the new rings of wood after the first year, but it also plays a prominent part in the occlusion of wounds, and the success of grafting depends largely upon the joining of the cambium of the scion to the cambium of the stock.

The Cambium is a delicate, juicy, film-like sheet or mantle which covers the root, trunk, branches and twigs like a huge glove. It consists of thin walled cells, densely filled with protoplasm and large nuclei, and divides up to form not only new

wood everywhere on its inner surface, but, to a smaller extent, living bark (*bast*) on its outer surface; the latter conveys the manufactured food from the leaves to the cambium, for it is important that it should be properly nourished if new zones of wood are to be produced. It is very sensitive to external injuries, and is protected by a jacket of corky tissue—the bark, hence mechanical injuries such as scraping and cutting bark by boys is one to be deprecated, as it reduces the protection by exposing the living parts of the trunk to insects and micro-organisms which cause disease. The zones of wood are repeated each year, in most trees, in a very definite and characteristic manner according to the species of tree.

Rings.—Having got some idea of the tissue responsible for the production of wood, let us now consider the rings of wood produced annually by the division of the Cambium. These rings, in many woods, are clearly marked because of the wood formed early in the year. Springwood as it is usually called, and which lies nearer the pith in the ring, is of a softer and looser nature, and therefore lighter in colour than the wood formed later in the season, and usually known as late or summer wood.

Why is there this contrast in tissue elements at different seasons of the year in many European woods? To some extent it must be due to tension caused by the tight bark compressing upon the increasing growth of wood, which, in its turn, is stretched and strained by the latter, as is proved by the longitudinal fissures which appear in the bark of many trees. Smooth bark is taut and presses upon the increasing girth, and if a longitudinal incision is made in such bark it will gape, while, if a strip of bark is cut off and then replaced immediately before it dries, it will be found impossible to make the edges meet. This means that bark presses on the growing wood, like a tightened iron band, which increases until the autumn is reached. This increased pressure causes the later formed wood elements to become flat and thicker walled. If an artificial local pressure is set up in early spring, by means of an iron band, and allowed to remain

during the growing season, at that particular place, cells similar to the summer ones will appear throughout the season, but if the pressure of the bark is relieved in summer by means of longitudinal cuts, then at those places, wood like the springwood will be formed. During the winter months the cambium is inactive, and this sudden cessation of growth causes a border line between the rings while the transverse pressure becomes reduced by the formation of cracks and fissures in the bark. But nutrition is also intimately associated with the formation of this contrasting tissue. In the following early spring with the released pressure, caused by the cracked and fissured bark, the reserve food, which is chiefly starch, and stored in the trunk, provides the cambium with its first supply of food and it at once commences to renew its activity, to form a lax thin-walled loose tissue. Later in the season with a plentiful supply of rich nitrogenous food the protoplasm plasters on the inner walls of the cells (except at certain points, to form pits) thick layers of a peculiar substance (or substances) which become changed into woody material known as lignin. What is wanted in structural timber is less of the soft light springwood and more of the closely packed thick walled summerwood, the latter having considerable influence upon the hardness of the timber. This, together with the uniformity in texture and width of the annually formed rings, are points of importance as to quality. What is wanted in Softwoods are slow grown narrow rings to reduce the amount of inner springwood, while in those Hardwoods having a porous ring such as Oak, Chestnut and Elm, fast grown timber is stronger and denser.

In some woods the prominent spring and summer zones are not so clearly defined, and may merge into each other as in Beech, while in others there is no differentiation discernible.

Care must be taken not to confuse with annual rings coloured irregular wavy bands or rings which are seen on the cross section of many heavy Indian and other tropical timbers. (Fig. 3). These bands, which consist usually of soft tissue (wood cells or

parenchyma), frequently fade out before completely encircling the log, or they anastomose; this does not occur with annual rings, however eccentric and close they may be. Sometimes these bands or lines consist of whitish resin-containing pores, commonly found in timbers belonging to the *Dipterocarpaceæ*. Timbers with these "false rings" as they are usually called, frequently have no distinguishable annual rings, and this is generally attributed to the season of growth not being sufficiently separated by periods of rest to form sharply marked zones of wood. Even in these woods, a cessation of growth such as caused by drought followed by a period of renewed activity may occasion the formation of rings which are perhaps more appropriately called "season" rings.

Annual rings show the age of a given section. At the butt of a trunk, if it includes the first year's growth, it will give the age of the tree. The tree may be 40 years old at the base, 25ft. up the trunk may be only 20 years old. The rings may also serve as records at different ages of the periods of suppression or activity.

The number of rings, as an indication of age, is not always infallible. It occasionally happens in trees that two rings are produced in one growing season. The growth of wood is the result of the physiological activity of the leaves, as they are the workshops where the food is manufactured, and if the tree is defoliated, for example, by frost in May, or by insects as sometimes happens to the Oak in July, another crop of leaves from dormant buds will frequently appear, resulting in the formation of a second ring.

Heartwood and Sapwood.—If we examine the cross cut end of any old oak stump, after the trunk has been felled, we see at once that it is clearly separated into two regions,—a darker, drier central portion surrounded by a pale moist softer portion. The deep coloured central part is called heartwood (*duramen*) and the outer part is known as sapwood (*alburnum*) sometimes referred to as "heart" and "sap" respectively. The heartwood is dead, and is usually the warehouse for storing colouring matter

or tannins, gums, resins, or mineral matter, which serve as effectual preservatives against decay. The colour often determines quality, for instance, the darker the heartwood of Larch, the greater its durability. Heartwood is heavier than the sapwood, which is less durable because the living cells of the sapwood contain starch and other organic foods, and therefore this wood is more liable to suffer from rot, resulting from the attacks of wood-destroying fungi.

Although not so durable, sapwood is more pliable than heartwood and the sapwood of some trees, such as Hickory and Ash, are valued for their bending quality.

In some trees there is no difference in colour between the "heart" and "sap" as shown in the old Oak stump, but in these cases, the "heart," if present, can frequently be distinguished by its relative dryness which would become obvious on microscopic investigation. The living elements of the sapwood (rays and soft tissue) lose their living contents when the wood becomes changed into heartwood. Such trees having no distinction between "heart" and "sap" are more likely to become hollow than trees having a coloured heartwood. That the absence of heartwood will not kill a tree, or that its presence is not even necessary for its life, is proved by the many hollow trunks, bearing in summer a healthy crop of leaves, the only disadvantages such trees suffer are want of firmness and stability.

In heartwood trees the more "heart" the better the wood when used as timber, and the presence of only a little, or its absence, is a sign that the wood has been cut from a young tree.

It must not be supposed that all trees possess heartwood. Many trees have no heartwood, but all trees without exception must have sapwood, as they could not live without it, seeing that it is the path travelled by the water containing mineral matter in solution from the roots to the leaves, there to be elaborated and manufactured into food. Until that has taken place, this solution could not be used for the growth of the tree any more than it could be used as food by a man. The heart-

wood, on the other hand, no longer performs the physiological function of conducting water and serves the tree only as a mechanical support.

Sometimes the boundary of the sapwood in the felled trunk is indicated by the discolouration brought about by fungi and other agencies, but this in no way prolongs its life as timber, unless it has been subject to an antiseptic treatment after being seasoned. The number of rings over which the sapwood extends is not the same in all trees, nor even in the same species of the same age.

The sapwood may be sharply defined from the heartwood as is the case in Yew and Robinia, or they may gradually merge one into the other.

The presence or absence of heartwood is not characteristic of all the species belonging to a single genus. In the Aspen Poplar there is no heartwood, while the White and Black Poplars have heartwood. Similarly the European Birch is a sapwood tree, while the American Birch is a heartwood tree. Other examples of sapwood trees are Hornbeam, Sycamore, Alder and Lime.

Internal Sapwood.—Douglas Fir and Oak sometimes show among the rings of coloured heartwood some colourless zones which are liable to decay. In the Oak specimen exhibited it should be noted how this colourless portion embedded in the darker heartwood has become attacked by Anobids while the heartwood remains untouched. These zones constitute what is known as "internal sapwood" and, like the outer sapwood, will take preservative treatment.

Internal Bark.—Sometimes at the butt end of the log there is an internal bark which also causes a defect. This is due to the fusion of vertical shoots while young, the number of shoots present being indicated by the number of piths. Higher up the trunk there will be only one centre, due to the additional conical layers of wood enclosing the young shoots. In the specimen of Lime exhibited there are two piths shown.

Wood Rays.—An old Oak stump on the cross-cut surface shows thin plates of variable length arranged radially (and vertically) through the wood. Sometimes they are called pith or medullary rays, two very inappropriate names, as they have no relation whatever with the pith or medulla, neither from the historical nor evolutionary standpoint. They arise from the cambium ring at irregular intervals during the growth in thickness, extending into the bast.

No softwood or hardwood is devoid of wood rays, although they differ considerably in size in different timbers, their number and size influencing the technical properties of wood, and, in some species, as in Oak, two sizes are found. In Hornbeam and Alder the broad rays appear to be due to the crowding together of the finer rays into bundles to form compound rays or "false rays." Rays are more conspicuous in hardwoods than in softwoods, while in the latter they are so fine and crowded that they often give quite a silken gloss to planed timber.

The physiological function of wood rays in the tree is to convey the various food substances, and in winter they usually act as storehouses for starch and other food substances, ready to supply the cambium in the coming spring. In fact, the presence or absence of reserve starch, in some trunks, under certain conditions serves to determine when the tree was felled.

Anatomy of Woods.

Wood may be composed of four different kinds of histological elements, although all of them are not necessarily present in the wood of every species. They form the bricks, so to speak, which build up the body of the tree, and those elements that are present are always firmly cemented together, the qualities depending in a large measure upon their character and arrangement. One character of wood which strikes us at once is its fibrous nature; it is shown clearly by the splintery fracture of a branch broken across the grain. The elements present in wood have a very definite arrangement, as everyone, who has

had experience in chopping wood, knows that it is easier to cut radially than tangentially, or when directed slantingly across the grain. This means that the elements normally run parallel to the trunk, and any variation from this straight-grained character would have a detrimental effect on the strength when used as structural timber. Spiral grain means that the fibres run abnormally in an oblique direction instead of vertically, and if split would show a twisted, fluted surface. It is generally indicated by the twistings of the bark. Softwoods appear to be more subject to spiral grain than hardwoods. It sometimes happens, for instance, in old trees of Tamarack, a species of Larch, (*Larix laricina*) that the inner wood is straight-grained while surrounded by an outer layer of spiral grain several inches thick.

The tenacity of wood when strained "along the grain" depends upon the tenacity of the walls of the fibres; when strained "across the grain" it depends upon the lateral adhesion of the sides of the fibres to each other. In softwoods, adhesion of the fibres is small, so that they are more easily split "along the grain" or torn across the fibres than in hardwoods.

SOFTWOODS. (PINES, FIRS, LARCHES, ETC.).

In softwoods we find the simplest type of tissue. It is this simple and regular structure which enables softwoods to be more easily worked and seasoned than hardwoods.

Tracheids.—It is this element which practically makes up the wood of softwoods. They are tiny elongated fibre-like cells of varying length, thin walled, and spindle shaped, the tapering ends "breaking-joint" with each other. On the walls are numerous bordered pits arranged in vertical rows that appear in section under the microscope as double concentric rings. They form double valves to regulate the distribution of water.

Wood-Cells (*Wood parenchyma*).—These are thin-walled isometric cells forming a soft tissue, and are only scantily scattered in softwoods, among the tracheids, as in Junipers. In some

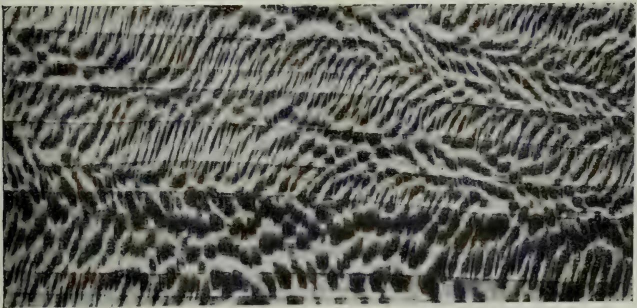
softwoods they consist of simple rows of cells, which afterwards become filled with resin. Yew wood is entirely free from this tissue. Wood cells always occur around the interior of resin pores, so characteristic of many softwoods.

Resin Pores appear as dark specks on the cross cut surface, sparsely distributed, forming long tubular spaces without true walls of their own, but lined by a circle of wood cells (*epithelium*), rich in protoplasm and large nuclei, which do not store starch like ordinary wood cells, but exude resin into the central passage. Resin pores extend to long distances through the wood, generally singly, but sometimes in groups, and run not only parallel to the axis of the tree, but also pass horizontally along the rays when the latter, in surface or tangential section of the wood, become lenticular or spindle-shaped. In Scots Pine we find both the linear and lenticular types of ray. These two kinds of resin pores communicate with one another, explaining the outpour of resin during the process of resin-tapping, and their contents have important effect on the technical properties of wood, such as durability and elasticity. Resin pores have nothing to do with the vessels or pores found only in hardwood trees, which are provided with a wall of their own. The irregular greyish outline of resin pores on the cross cut end and their isolated distribution as they appear under a lens should help to distinguish the two. On the longitudinal surfaces they appear as fine yellowish or brownish streaks, and occur in Pines, Spruces, Hemlocks, Douglas Fir, and Larch, but are absent in Silver Fir, Yew and Cypresses. Their presence or absence help in the identification of softwoods.

Hardwoods. (Oaks, Elms, Chestnut, etc.)

These are much more complicated in structure, most of them containing all the four elements already referred to. The most conspicuous are the wood pores, technically called vessels. These are hollow tubes made up of cells arranged vertically with open ends set one above the other like empty barrels with their

1. OAK (Quercus) Silver-grain produced by large Rays.



2. PLANE (Platanus) Silver-grain produced by broad and crowded Rays.

3. LIME (Tilia) Silver-grain. produced by fine Rays.

Photo: J. A. S. STENDALL.

FIG. 1. Radial or quarter-cut boards, showing silver-grain. The horizontal lines clearly shown in Nos. 1 and 2 are Ring-boundaries. Page 53.

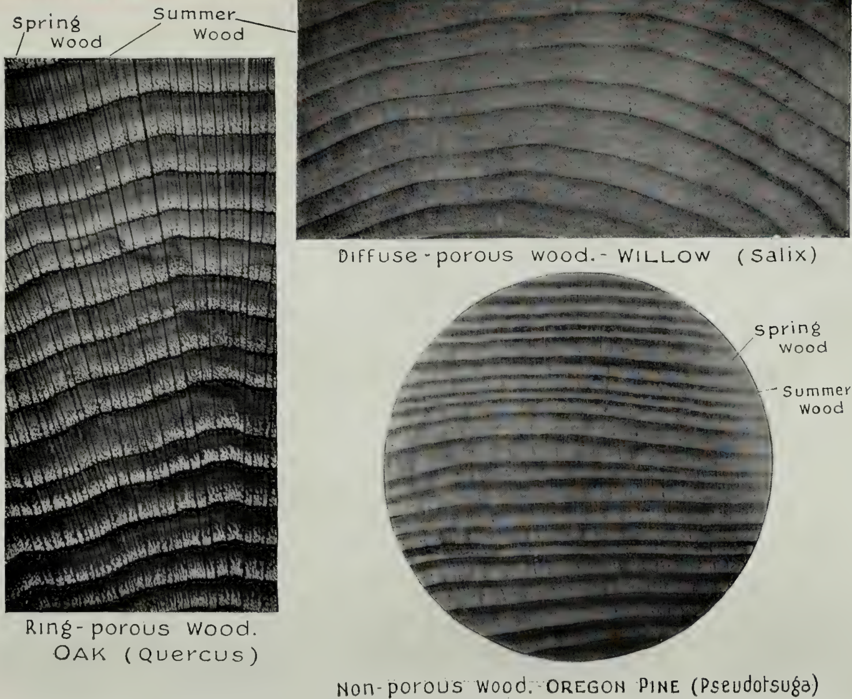
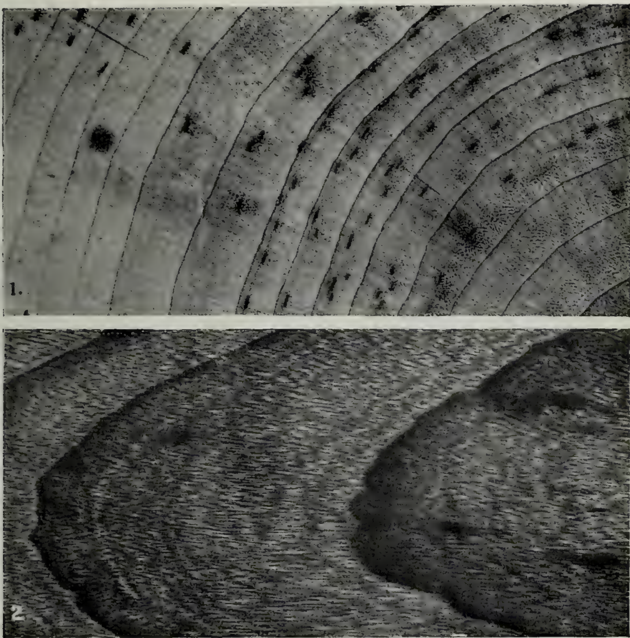
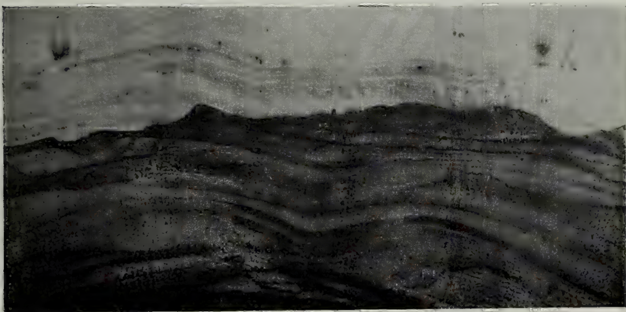


Photo: J. A. S. Stendall

Fig. 2, showing different types of wood. (Slightly reduced). Page 51.



BIRCH (Betula) showing Pith Flecks.
1. Transverse section. 2. Tangential section.



OLIVE (Olea europea) showing "False Rings"

Photo: J. A. S. STENDALL.

FIG. 3. Pith Flecks, page 53.
"False Rings," page 44.

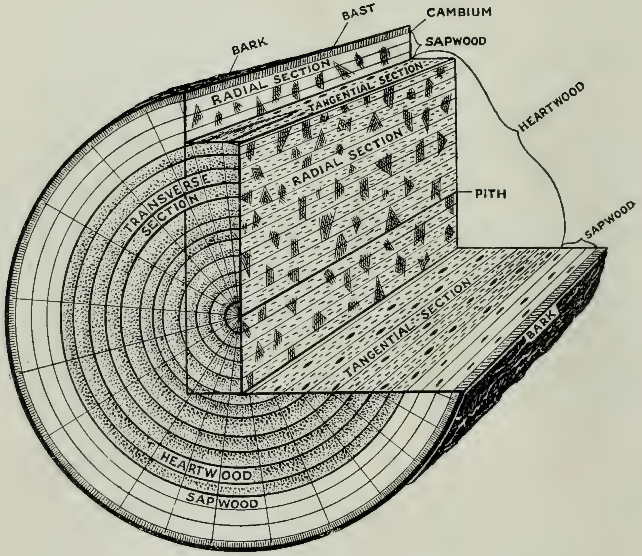


FIG. 4, showing the three sections or cuts in relation to the log, and the different parts of the trunk. Page 53.

ends knocked out, and usually having on their walls bordered pits and reticulated thickenings. A vessel, then, is a cell fusion, while a tracheid is a cell. They may range from the diameter of a pin, as in Oak, down to those too small to be seen with the naked eye, as in Willow. Hardwoods on this account are sometimes called "porous woods," while softwoods having no vessels are frequently called "non-porous woods."

Among the hardwoods, those forming a prominent porous ring are sometimes described as "Ring porous woods" such as Oak, Chestnut, and Elm, while those examples where the pores are more or less evenly distributed throughout the entire ring are frequently described as "Diffuse porous woods" such as Birch, Hornbeam, Alder, Poplar, and Willow. The rings are best defined in ring-porous woods and non-porous woods. (Fig. 2).

Tyloses.—These are ingrowths of cells adjoining the pore (vessel) of some hardwoods or a resin pore of some softwoods, or more rarely in the tracheids of such hardwoods as sweet gum. (*Liquidamber styraciflua*). These cells make their invasion by pushing their way through the pits or unthickened portions of the walls into the cavity. They contain protoplasm and in some cases nuclei, and may divide and completely plug up the lumina of the elements which they invade, forming partition walls at irregular intervals throughout the entire length of the tube.

Tyloses occur in many woods, sometimes few and sometimes in abundance. We have examples in some Oaks, Sycamore, Robinia, and Snakewood (*Brosimum aubletti*). In the last named the tyloses become thickened and converted into stone cells. Tyloses originate under various conditions, but are more usually found in connection with the transition of the sapwood into heartwood, especially in those woods with large pores, rendering the heartwood impervious to water. They are also produced in the pores of wood wherever local injury takes place, as in cut branches, and they develop in the cementing tissue during the progress of engrafting.

Snow points out that air can be readily blown through

several feet of Red Oak, even if unseasoned, because tyloses are not present in the pores, but a pressure of 100 lbs. per square inch is sometimes insufficient to force air through a single inch of unseasoned White Oak, because the pores of this species contain abundant tyloses. They thus tend to retard the introduction of foreign fluids such as antiseptics.

Wood Fibres.—These are thread-like cells, not unlike tracheids in outline, but usually longer and with much thicker walls, which is a characteristic feature. Sometimes they are so thick as to show hardly any cell cavity, and they are devoid of the characteristic bordered pits of the tracheids of softwoods, the pits being small and slit-like. They are not found in softwoods, but they form the principal structure in hardwoods. These fibres contribute largely to the strength and hardness of hardwoods, and the more they predominate the better.

According to E. C. Jeffrey a peculiar kind of fibre is found in some Oaks and in some leguminous woods, caused by the inner wall of the fibre becoming mucilaginous. Woods having mucilaginous fibres are stated to be of special value in cabinet work on account of their relative immunity from shrinking and swelling, while the numerous mucilaginous fibres composing the woods of False Acacia (*Robinia Pseudacacia*) make the wood very suitable for trenails in the construction of wooden ships, as they neither swell unduly in water nor shrink in the sun.

Wood Cells (*Wood parenchyma*). These are much more abundant in hardwoods than in softwoods Sometimes they are scattered in characteristic fashion among the wood fibres and are usually lighter in colour than the surrounding tissue. They often adjoin the vessels and become a useful aid in identifying timbers. In the Oak they form radial lines in the summer wood (Fig. 2), while in the Elm they surround the pores to form tangential lines. In Corkwoods, such as Balsa wood (*Ochroma Lagopus*) exhibited, the wood consists in a large part of wood cells. The wood cell tissue of the sapwood is used during the resting season as a storehouse for reserve food material such as starch.

Pith Flecks.—Peculiar patches which have a pathologic origin are sometimes found in wood, and usually appear coloured and well defined on the cross cut section of logs, or on tangential boards. In Hornbeam and Cherry they are inconspicuous, owing to the colour of the wood. They frequently occur in Willow, Poplar, Alder, Birch, Lime, and many trees belonging to the *Rosaceæ.* They are the burrows caused by the larvae of a dipterous insect (*Tipula*) feeding upon the cambium during the growing season, and afterwards becoming occluded with wound tissue of a soft cellular nature. (Fig. 3).

Surfaces of Timber.

In cutting timber there are three surfaces or exposures, and in order to understand the structure of timber, it is important to study the three planes of section : (Fig. 4) (1) the transverse or cross cut section, i.e. at right angles to the long axis ; on this surface the annual layers appear as concentric rings and the rays as long lines as it shows the latter in longitudinal view from above or below : (2) the radial cut or quarter-sawed timber, i.e. cut towards the centre of the log parallel with the rays : the rings then appear as vertical lines, and crossing these at right angles are the wood rays displaying their longitudinal view from the side to form flat expanded surfaces known as silver grain in large rayed woods : (Fig. 5) (3) the tangential surface or slab cut, which is parallel to the bark and at right angles to the rays. Here the rays are not conspicuous, but under a lens appear as short pointed streaks distributed irregularly among the other tissue, this is a very important surface, however, when studying timber, because we get some idea as to the height and breadth of rays as we view them in transverse section. The rings appear on this surface as ellipses or hyperbolas in the centre and open stripes at the side. To grasp this, one must remember that the rings are hollow cones nested one within another.

Boards cut with the rays (i.e. radial or quartered) are stronger and less liable to warp and split than those cut across the rays (tangential) which form the ordinary boards, Tangential cuts may, however, present a pleasing appearance as in Elms. It is important to note, as the late Thomas Laslett has pointed out, that in tangential boards there is an outside and inside to every board, and especially should this be noted in floor boards with the strain of traffic. These should be laid so as to expose the youngest or outermost rings; otherwise if laid with the older or innermost rings exposed they will shell out, forming hollows in the boards. In other words the convex side should be uppermost.

Timber *versus* Metal.

From the earliest times wood has been used in construction, and for making implements and utensils wherever it grew, at first by primitive stone tools; but later, with metal tools, wood was more extensively used, and to-day, with the advance of civilization, it is the most widely used material in spite of its replacement to some extent by iron and stone in buildings.

Timber used in construction has many advantages over metal.

Advantages:—

1. One great feature is that wood, being an organic structure, can be reproduced. The cutting of forests has advanced at a greater rate than they have been regenerated, yet, under a well conducted forest management, forests could be made to yield indefinitely. With inorganic materials such as metal and stone, the more extensively they are utilised, the quicker the supply becomes exhausted with no opportunity to replace them.
2. Timber is stronger than is generally supposed. In tensile strength (resistance to a pull lengthwise of the grain) a bar of hickory exceeds a similar bar of iron or steel of the same weight and height. A 10 ft. beam of hard

pine requires considerably more load to bend it by one inch than a similar bar of iron of the same weight and length.

3. Timber can stand a far greater distorsion than metal without losing its power to regain its original position. In this way timber gives a warning before reaching breaking point. In many cases of damage or fracture it is easier to replace, and it can be shaped and reshaped with greater ease than metals.
4. 12″ wooden beams, though combustible, require a good deal of heat to destroy them, because the surface becomes charred and protects the inner portion. Timber beams will often remain in position, after a fire, and carry a load, while iron and steel under the same heat would twist out of shape and fall.
5. Timber does not corrode like metal. It lasts longer, even without paint, in exposed situations. With metal, access to moist air must be prevented. Impurities in iron cause brittleness and weakness. Timber continually under water lasts longer than iron or steel.
6. Timber is a poor conductor of heat and electricity; it is pleasant to touch, is more artistic, and has a beauty absent in metal, and has none of the injurious effects of iron and steel.
7. Pieces of wood may be strongly glued together. Metals, on the other hand, would require welding or soldering. By too frequent reheating and forging, wrought iron is weakened.
8. Certain timbers may be used for casks, remaining unaffected, and imparting no disagreeable flavour to their liquid contents, where metals would be objectionable or even poisonous. The elasticity of certain woods renders them superior to any metal for the resonant parts of musical instruments,

So far, we have been considering the advantages of wood over metal. We must not, however, overlook some of the disadvantages.

Disadvantages :—

1. Wood cannot be melted or cast. Rods, or thin sheets of wood, however, can be bent when steamed, and when reduced to pulp can be moulded into almost any shape.
2. It shrinks and expands with variations of moisture a good deal more than metal under ordinary variations of temperature.
3. Being more easily crushed than iron, it is not so well suited for bearing the greatest weight or for resisting heavy blows.
4. For commercial buildings greater strength is obtained in steel, less depth of girder is required, and thus a gain in height.

Sir T. G. Jackson, R.A., in his book "Reason in Architecture," 1906, p. 171, says: "Iron construction is really still in an experimental stage; we do not yet know how it will stand the test of time. Meanwhile, all experience hitherto tends to show that an Architect who wishes his building to go down to posterity will do wisely to let iron play as small a part as possible in his construction. It has been prophesied that 30 years hence no one will employ iron in his buildings, at all events, as the main element in their fabric. The failure of a single tie-rod seems to have been the cause of the collapse of the roof at Charing Cross Station, and it is certain that no monster roof of that kind will ever be put up again. To say nothing of great railways and other engineering works, it is disquieting to think of the miles and miles of streets in London and other towns where the whole of the upper storeys rest on girders accessible to atmospheric changes, liable to rust and fatigue and possible injury by vibration, which no one can examine and which cannot be repainted."

It would be interesting to know the opinions of our local architects and civil engineers seeing it is 12 years since these

remarks were published. Perhaps the best conclusion is a happy combination of both, because the properties of one so largely supplement those of the other.

Names of Timbers.

The multiplicity of common and trade names of timbers is so bewildering and misleading that one is forced to wonder why Architects and others, whose duty it is to draw up specifications, do not recognize the importance of botanical names in order that the timber wanted may be properly defined and many difficulties avoided; especially is this important now that new kinds of timbers may be used in place of others. Timbers from different countries frequently go under different names, making it appear that they are more numerous than is actually the case, and often they are brought from afar because the same species nearer at hand is not recognized by its local name. Moreover popular and native names may in the course of time disappear and be replaced by others.

What we call Pitchpine (*Pinus palustris*) has something like 30 common names, and in America is usually called Longleaf or Georgian Pine, their pitchpine being *Pinus rigida*, an inferior species. Weymouth Pine (*P. strobus*) is known on our market as Yellow Pine, but is called in America White Pine. The wood of Douglas Fir, (*Pseudo-tsuga Douglasii*) if wide-ringed, is usually reddish and is known as "red-fir" and "oregon pine," and the popular belief is that these timbers come from different species of trees whereas the two grades are obtained from the same species. Intermediate grades are also common. "Southern Pine" of the United States includes three species. An Architect specifying for Southern Pine may be supplied with any or all of the pines in question.

The name "Mahogany" is not now confined, as it originally was, to a single species, (*Swietenia Mahagoni*) but to a number of timbers from many different genera and species of trees which differ widely in anatomical structure. Some 70 kinds of timber

are sold under the name of Mahogany. A good paper on the recognition of some of the different kinds of Mahoganies, by Dr. Dixon of Trinity College, which he read before the Royal Dublin Society, was published in December last. Dr. Dixon describes some 45 kinds of "Mahogany" which he had the opportunity of examining. The paper is illustrated by excellent photographs, the tangential sections being particularly valuable in displaying the area occupied by the rays in the different woods.

Enough has been said to show that common names are confusing, which makes it very possible to substitute timber of poor quality for better timber. This leads to the necessity of a reliable means of recognizing commercial woods. The wood design produced by the cambium when viewed in the three directions offers the most reliable means for the identification of timbers, although there are accessory characters such as colour, taste, odour, bark (if present), which may be helpful in conjunction with structural characters. Even structural character does not always render identification easy between related species, as in Oaks. Although an Oak wood is perhaps the easiest to identify, yet it is one of the most complicated as regards its structure, while softwoods, although much simpler in structure, are more difficult to identify than hardwoods, and frequently require the aid of the microscope for decision.

In attempting the identification of wood, one should not forget the observations of many good workers, and particularly the labours of H. Nördlinger, R. B. Hough, J. S. Gamble, F.R.S., on Indian Timbers; the late Professor Marshall Ward, F.R.S., and Herbert Stone. Many attempts have been made to establish keys to "run down" timbers, but these generally deal with only certain woods.

Mr. Herbert Stone, the author of an excellent book—"The Timbers of Commerce and their identification," and other works, who has examined many thousands of timbers, has devoted much time and thought to the construction of a key. An interesting account of Mr. Stone's suggestions for such a key will be found

in a discussion on a paper on "Wood: its identification and mechanical properties," by W. H. Barling, which appears in the Aeronautical Journal for May, 1918.

Anyone wishing to take up the study of the identification of timbers will find in the Museum many examples to commence with. We have Ceylon timbers presented to this Society by Sir James Emerson Tennant, British Guiana timbers in the Grainger collection, Canadian and Australian timbers, and Queensland and other timbers given by Mr. Herbert Stone of the Forestry School at Cambridge.

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The following books and pamphlets will be found very useful to those who wish to expand their knowledge on the points raised in the lecture. All of them will be found in the Reference Department, Public Library, and the writer is indebted to the Authors of many of those mentioned.

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14th January, 1919.

FRONTIERS OF FRANCE.

By Prof. Granville A. J. Cole, F.R.S., M.R.I.A.

(Abstract by the Lecturer.)

Ancient Gaul, the predecessor of France, received its civilization from the spreading Roman Empire, and in turn impressed that civilisation, and a speech of Latin origin, on the Franks and Goths who seized upon the Roman lands. The Goths sided with the Romans against the barbarous Huns, and the dwellers in Gaul did much to maintain the traditions of law and order transmitted to them by Roman rule. The divisions of western Europe in the middle ages led to the struggle between a growing kingdom of France on the one hand and the English and the Burgundians on the other. The frontiers of France as we now know them were the dream of the young peasant girl, Jeanne d'Arc. In her 19th year, by faith and devotion to a visionary cause, deserted by her king and martyred by the English, she had laid the foundations of a united France.

The Phocaeans brought Greek civilization to Massala (Marseilles) in 600 B.C., and this harbour on the Mediterranean frontier remained the great port of entry for the Romans. The Rhône valley west of it gave easy access to the interior, and to-day Marseilles is the link between Paris and the colonial lands of France in northern Africa. From it the French have taken up the mantle of imperial Rome, and their heroic actions on the Meuse and on the Somme have been discussed on the steps of Tunisian mosques and supported by Moslem volunteers.

The rampart of the Pyrenees forms a highly effective and natural frontier between France and the Iberian block, and checked in critical centuries the progress of the Moorish Cali-

phates. From its western end the great confluent delta of the Garonne and its tributaries spreads northwards, forming the level country of the Landes, margined by sand-dunes and swept by the Atlantic winds. This ocean frontier was known to the Phoenicians, and it is said that the first knowledge of letters reached Gaul through the estuary of the Seine. The bleak promontory of Brittany, which gave so many seamen to the navies of France, is part of "Armorican" Europe, a folded mass far older than the Paris Basin, the Pyrenees, or the Alps; it is repeated in Cornwall and southern Ireland, and can be traced through the Ardennes and eastward far across the Rhine.

The special "narrow sea" of the old writers, the link between the North Sea and the English Channel, completes the sea-frontier of England, but has allowed of frequent rivalry between dwellers on the opposing shores. Across it the Normans converted England into "the most successful colony of France," while their anglicized descendants made frequent raids upon what they claimed as their rightful soil in Picardy. The holding of Calais by those who held the port of Dover was long regarded as essential to England's safety. A permanent and warm alliance with France offers a far better guarantee at the present day. Eastward from the narrow sea, the northern frontier runs across the level lands of Flanders, where natural boundaries are hard to find. Here nation has warred with nation for supremacy in western Europe, and the open Netherlands have been again and again overrun in struggles with which they had no immediate concern. It is no accident that the invaders of France in 1914, and the victorious allies marching northward in the autumn of 1918, traversed the ground of Conde's, Marlborough's, and Wellington's campaigns.

The frontier is far better defined when we reach the Armorican ridge of the Ardennes, which leads us eastward to the Rhine-trough. The mass of the Vosges forms a natural rim to France above the Rhine, though the river itself must be accepted as the actual frontier of Alsace. This country,

formerly divided among small states and German bishoprics, was annexed to France at the close of the thirty years' war, and by the wise treatment of 200 years became thoroughly French in spirit. The language was not interfered with in the German-speaking districts, and it was Alsatian-Strassburg in 1792 that Rouget de l'Isle, a young captain of Engineers, composed and sang for the first time verses that he called "A song of the Army of the Rhine." That army had flung back the coalised Prussians and Austrians to the natural edge of France, and the song, renamed the Marseillaise, remains the anthem of the great French Republic.

France in 1870 paid the price of a rash attempt to cross the Rhine in arms, and the frontier was broken by the counter-onslaught of Bavarians and Prussians, who swept their opponents into Metz and northward along the Meuse vale to Sedan, where the second French empire fell, five weeks after the opening of the war. The new frontier that was exacted by the victors in 1871 was determined strategically, and was designed to secure the iron mines of Lorraine as well as to keep back France from contact with the Rhine. From unconquered Belfort, the Juras provide a region very difficult to traverse, where the valleys run south-westward, parallel with the axes of folding in the range; and then we reach, ranging from Mont Blanc to the Mediterranean, the unrivalled frontier of the Alps.

The nature of the superb but little visited region of Haute Savoie and Dauphiné may be illustrated by the traverse of seventy miles from Grenoble across the Lantaret Pass, and through the frontier-fortress of Briançon to the wall of Italy at Mont-Genèvre. Right down to the Maritime Alps, equal difficulties must be encountered by an invader, and Charles V. lost two armies in his attempts across the hills on Toulon. Again, in 1707, Prince Eugène and the Duc de Savoie lost 10,000 men before Toulon and in their enforced retreat. At Nice and Monte Carlo, the range is cut across by the sea, so that the road and

railway into Italy have to find what space they can and often tunnel through projecting spurs.

The Alsatian frontier on the Rhine has now been recovered for the French. The desecrated northern frontier has been crossed by the armies of the *Entente* at the final collapse of terrorism after four years of devastating war. The vigour of the French defence is typified for us by the stand on the Meuse at Verdun and in the trenches across the open plateaus consecrated by the home of Jeanne the Maid. It may be illustrated in a concrete form by the chase of the Zeppelins from Paris southward on October 20th, 1917, when four of the invading airships were brought down between Lunéville and the *cluse* of Sisteron, kept by the vigilance of defensive aircraft from escaping into German lands. France has held her frontiers as she held them once before at Valmy and Jémappes, and it was with a wise foreknowledge that M. Driver in 1917 named his fine bust of the Republic, worn by conflict but confident of right, *La Republique de la Victorie.*

Report and Proceedings

OF THE

BELFAST

Natural History and Philosophical Society

FOR THE

SESSION 1919-20.

BELFAST:
MAYNE, BOYD & SON, LTD., 2 CORPORATION STREET
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1921.

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BELFAST NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.

Officers and Council of Management for 1919-20.

President:

PROF. GREGG WILSON, O.B.E., M.A., D.SC., PH.D., M.R.I.A.

Vice-Presidents:

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S. W. ALLWORTHY, M.A., M.D., F.C.S.
PROF. JAMES A. LINDSAY, M.A., F.R.C.P.
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Hon. Secretary:

ARTHUR DEANE.

Council:

W. B. BURROWES. E. J. ELLIOTT. H. C. LAWLOR, M.R.I.A. WILLIAM SWANSTON, F.G.S. PROFESSOR GREGG WILSON, D.SC., M.R.I.A.	*Retire* 1920.
JOHN M. FINNEGAN, B.A., B.SC. PROFESSOR J. A. LINDSAY, M.A., F.R.C.P. HENRY RIDDELL, M.E., M.I.M.E. ROBERT M. YOUNG, M.A., M.R.I.A., J.P. PROFESSOR W. ST. CLAIR SYMMERS, M.B.	*Retire* 1921.
SIR CHARLES BRETT. *SIR JOHN BYERS, M.A., M.D., M.A.O. S. W. ALLWORTHY, M.A., M.D., F.C.S. WILLIAM FAREN. ARTHUR DEANE.	*Retire* 1922.

*Died September 20, 1920.

Belfast Natural History and Philosophical Society.

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ESTABLISHED 1821.

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CONSTITUTION.

The membership of the Society consists of Shareholders, Members under the new scheme authorized by the Society, Annual Subscribers (Associates), Honorary Members and Honorary Associates.

A holder of one share pays an annual contribution of ten shillings ; a holder of two shares (in one certificate) an annual contribution of five shillings ; while a holder of three or more shares (in one certificate) is exempt from annual payments. Shares on which the annual payments as above are in arrear are liable to forfeiture. The Council retain the right to decline to consolidate two or more share certificates into one certificate. Members under the new Scheme are elected by the Council, pay ten shillings per annum subscription, and have the right to vote on all questions not affecting the ownership of the property of the Society.

Annual Subscribers (Associates) pay £1 1s. 0d. (one guinea), due 1st November each year in advance.

A general meeting of Shareholders and Members is held annually in May or June, or as soon thereafter as convenient, to receive the Report of the Council and the Statement of Accounts for the preceding year, to elect members of Council, to replace those retiring by rotation or for other reasons, and to transact any other business incidental to an Annual Meeting.

The Council elect from among their own number a President and other officers of the Society.

Each member has the right of personal attendance at the Ordinary lectures of the Society, and has the privilege of introducing two friends for admission to such. The Session for lectures extends from November to May.

Any further information required may be obtained from the Honorary Secretary at :—The Museum, College Square North, Belfast.

12th November, 1918.

IRISH WOODS AND FORESTS.

Illustrated by Lantern Slides.

By Professor Augustine Henry, M.A.,
Professor of Forestry, Royal College of Science, Dublin.

Professor Henry, in the course of his address, which was illustrated by many beautiful views, described how trees growing on bog-land had been killed by the change of climate which the country had experienced some 3,000 years ago, and how the bog had since grown above their roots to a considerable depth which explained the presence of tree stumps and roots being found twenty or more feet below the bog surface. The lecturer emphasised the very great repressive effect of wind on the growth of trees, and showed how important was the proper selection, not only of sites for tree planting for timber purposes, but the species of trees best suited to resist wind in exposed situations. A brief historical account was given of some of the more famous woods—principally Oak woods—in the North of Ireland, including the historic "derry," which was cut down to build the City of Londonderry. The forests along the Lagan Valley and in the lower Mourne district were also dealt with. In conclusion, the Professor said "the reafforestation of those parts of Ireland which were suitable for the purpose should be approached in a systematic way, otherwise attempts of this kind would be of little practical good."

At the close a vote of thanks to Professor Henry was passed by acclamation.

26th February, 1919.

"THE STORY OF PORCELAIN."

By Mr. Charles E. White.

In the course of an interesting address, Mr. White pointed out that commercial competition had always tended towards deterioration in the artistic merits of porcelain ; the cheapening of prices resulting from this competition, and the cutting down of wages had often made it impossible for an artist to put his soul into the work. This had helped to bring about the deterioration in style and the introduction of transfer printing on porcelain.

Several lantern slides were shown of Belleek porcelain, in which the effect of temperament and national characteristics were displayed. In addition to a full series of slides Mr. White illustrated his remarks by beautiful specimens of the potter's art.

A hearty vote of thanks was accorded the lecturer on the motion of Mr. H. C. Lawlor, seconded by Mr. R. S. Lepper.

8th April, 1919.

"THE ROMANCE OF TUBERCULOSIS."

By Dr. ANDREW TRIMBLE, D.P.H.,
Chief Tuberculosis Officer, Belfast.

Professor W. St. Clair Symmers presided, and briefly introduced the lecturer, remarking that tuberculosis was the most dreadful of all human diseases, and he trusted that one of the results of the lecture would be to reawaken in Belfast that keen interest which they had in the disease some few years ago ; he was perfectly certain that the campaign to which he referred did an untold amount of good.

Dr. Trimble said he had noticed that the history of a scoundrel was always much more interesting to the bulk of mankind than the history of a saint. If he was correct in his observation, then the subject of tuberculosis should be of thrilling interest, for tuberculosis might well be called the diabolus amongst the demons of disease—the scoundrel amongst the scourges of humanity. It was hoary with age, and yet had all the energy of youth. It attacked the prince in his palace, and the peasant in his hovel—but preferred the peasant as the easier prey. It neither pitied the young nor honoured the aged, although it preferred to wait till its victim had come to maturity, and, just at the moment when life was inviting and hopes were high, it dashed the cup of youth in pieces to the ground. It attacked the animal as well as man. It settled in every tissue of the body, although it preferred the more delicate and vital parts. It attacked the strong as well as the weak, but preferred the weak. It observed the lifeboat rule, "Women and children first," with an irony that was sardonic. It gave the flush of health to its victim at the moment when it was about to push him over into the grave, and instead of warning its victim of his

impending doom, it blinded his eyes to his true condition and gave him the false hope of betterment and life. And all that it did in a manner so wholesale and sweeping that it killed annually in the Empire more victims than we lost each year since the greatest war in history began, and wounded twice as many people as were wounded in warfare. To be specific, more than 60,000 people died annually in the United Kingdom, while it was computed that there were at least seven actively tubercular subjects to each one who died, or more than 400,000. The history of tuberculosis was not a chapter in the history of medicine : it was part and parcel of history itself. Though the recorded historical observation and tabulation of symptoms began about the time of Hippocrates, it was obvious that symptoms of tuberculosis must have been observed long before, for there was no reason to doubt that the bacillus showed its activities almost at the dawn of civilization. Proceeding, the lecturer sketched the history of the study tuberculosis in a most interesting manner, dwelling particularly upon the work of Anenbrugger, Laennec, Jean Antoine Villemin, Cohnheim, and Koch. The final discovery, by the last-named—the cause of tuberclosis—said the lecturer, was not less epoch-making, or less important to humanity, than was the discovery by Columbus of America. Let them turn now to the tubercle bacillus, and hear what he had to say for himself. He had called him a scoundrel, but if he were a criminal being tried at the bar of humanity, he would have a right to say what he could for himself. If they gave him that opportunity, he fancied this was something like what the bacillus would say in his defence :—"You have accused me of being the cause of much suffering, and of innumerable deaths ; of having slain without pity the young and the old from time immemorial. But I would remind you that in that respect I have done no more than you yourselves—the lords of creation—have been doing for the past four and a half years. If I reproduce myself to the damage of my host, I would like you to remember that it was not I who put myself in the position of doing this injury. I can neither walk, swim, nor

fly, and if I find myself in the body of either man or animal I must have been blown there by the wind, or introduced by the careless and filthy habits of the individual. For the rest, I have but obeyed the law of nature, that the fittest survives. But allow me to point out to you that the death of my host, far from being my object, is to me an unmitigated calamity. For, being buried with him in the earth, I soon follow him into decay for want of warmth and food. I have my place in nature, as you have yours, and if you will not compel me to enter your bodies, I am content to remain outside, fulfilling my function in some other fashion. But after examining all the facts, can you say I have been an unmitigated evil? I have altered the destiny of many an individual. I have had an effect, not always for the worse, but often for the better, on art, music, and literature. I have called out and developed tender sympathies and loving devotion that otherwise might have lain dormant, and if now you understand that I am an accompaniment of poverty, crowded housing, careless and dirty personal habits, and of Cain-like indifference to brotherly feelings, and if, understanding this, you recognize the necessity for more and better food, for decent housing accommodation, for parental solicitude for little children, for personal cleanliness, and if, realizing this necessity, you are resolved to remedy these evil conditions so far as lies in your power, you will at one stroke have removed the opportunity of which I—with a horde of other evil spirits of infectious diseases—have taken advantage, and you will at the same time have laid the foundation of a happier and healthier humanity." The lecturer went on to say that he thought the jury, having heard such a speech, would bring in a verdict of "guilty, but with extenuating circumstances." It might be well, however, to take the admonition of the bacillus to heart, and to put his suggestions into practice. He had mentioned in his speech a circumstance that had not commonly been noted—that of the effect which he had had upon the arts and literature. Might he (Dr. Trimble) say at once that he believed there was a great deal of

truth in what he had said. The tubercle bacillus was a traitor in that he had not failed to attack royalty—our own Richard III. apparently suffered from tuberculosis of the spine. Again he hesitated not to strike down the little Dauphin of France, "the king who never reigned." Amongst artists, he laid his hand on Watteau and Sebastian Le Sage. Amongst poets, he shortened the lives of Henry K. White, Keats, Elizabeth Barrett Browning, Sidney Lanier, Henley, and Francis Thompson, while it was on account of tuberculosis that Shelley made the journey to Italy, where he was destined to meet with so tragic a death. He stilled the notes of Henry Purcell, Paganini, Chopin, and Weber. Amongst preachers, he carried off George Herbert, and attempted, but failed, to carry off John Wesley. Even famous soldiers fell in combat with him, for he sent to an early grave one of Napoleon's most famous Generals—Hoche. Historians had bowed before his ravages; Green died at 46 dictating the end of his English History from his death-bed, and Smollett fell before him. Novelists had succumbed to his blows, two of the Brontes and Robert Louis Stevenson being amongst his victims. Litterateurs such as Thoreau, John Addington Symonds, and Heinrich Heine fell in the unequal contest with him. Wits like Artemus Ward and Tom Hood made the world laugh while they were dying from his assaults, nor must they forget the wisdom, so akin to wit, of Æsop, nor the wit, so akin to wisdom, of our own Mr. Punch—the modern Punchinello. Finally, it was the tubercle bacillus that drove Cecil John Rhodes to seek for health in South Africa, and, incidentally, to lay the foundations of an empire. No serious attempt had yet been made to assess the influence of disease on intellectual workmanship. The tubercle bacillus undoubtedly had on more than one occasion altered the course of destiny—had been, indeed, destiny itself.

Questions were asked and answered, and at the close a vote of thanks was heartily accorded Dr. Trimble, on the proposition of Professor Symmers, who expressed the hope that the doctor would give an address in the near future on the work upon which he was engaged in Belfast.

ANNUAL MEETING.

SESSION 1918—1919

Held in the Museum, College Square North, on Tuesday evening, 11th November, 1919, at eight o'clock.

On the motion of Mr. H. C. Lawlor, the chair was taken by Professor Gregg Wilson.

The Chairman referred in feeling terms to the death of Mr. John Horner. On the motion of the Chairman, seconded by Councillor Henry Riddell, the following resolution was passed in silence :—

> "That this Annual Meeting record its sense of the great loss the Society has sustained by the death of Mr. John Horner, which took place on the 25th November, 1919. Mr. Horner was an active member since the year 1887, and took a keen interest in all that pertained to the welfare of the Society. He served as Honorary Treasurer from 1904 to 1911, and at the time of his death was a Vice-President and Honorary Librarian."

The Honorary Secretary was instructed to forward a copy of this Resolution to Mrs. Horner and to convey to her the Society's sincere sympathy in her sad bereavement.

COUNCIL'S REPORT.

The following report of the Council for the year was submitted by the Hon. Secretary (Mr. J. M. Finnegan) and adopted :—

The Council of the Society desires to submit its report of the working of the Society during the past session. Six ordinary meetings have been held, and it is glad to say that the lecture

on each occasion was well attended. The list of the lectures and lecturers is as follows :—

	1918.	
1st.	Nov. 12th.	"Irish Woods and Forests." By Professor Henry, M.A., Professor of Forestry, Royal College of Science, Dublin.
2nd.	Dec. 10th.	"A War Memorial for Belfast." By Mr. Alec Wilson, M.R.I.A.
	1919.	
3rd.	Jan. 14th.	"Frontiers of France." By Professor Grenville A. Cole, F.R.S., of the Royal College of Science, Dublin.
4th.	Feb. 25th.	"The Story of Porcelain." By Mr. Charles E. White.
5th.	March 11th.	Trees: the character, structure, and properties of wood. By Mr. Arthur Deane, Curator Municipal Art Gallery and Museum, Belfast.
6th.	April 8th.	"The Romance of Tuberculosis." By Dr. Andrew Trimble, D.P.H., J.P., Chief Tuberculosis Officer, Belfast.

All the lectures were well illustrated by lantern slides, and, in some instances, further illustration was obtained from specimens.

Proceedings.

A new departure has been made in regard to papers intended for publication: instead of waiting until the end of the session and printing in the Proceedings, papers intended for publication are sent to the printers as soon as possible after the lectures have been given, in order that printed copies may be put into the hands of members at an earlier date. The Council hope, that in future, all lecturers will assist in this new arrangement by

handing their papers to the Hon. Secretary without delay, so that they may be submitted to the Publication Sub-Commmittee at once. A certain number of the printed papers will be bound as Transactions for distribution.

Archaeological Section.

The Archaeological Section which was formed during the session 1917-18 under the chairmanship of Sir Charles Brett, appears to justify its existence. A separate report of its activities will be submitted to the Sectional Annual Meeting by the Hon. Secretary of the Section, Mr. H. C. Lawlor, during the present month. (See pp. 77—86.)

Hon. Secretary's Resignation.

Your Council is sorry to have to report that Mr. J. M. Finnegan, B.A., B.Sc., who has served the Society as Hon. Sec. since 1912, has resigned, and that Mr. J. W. Storey, B.A., who has acted as Assistant Secretary, has also resigned, having been appointed as Secretary in Ireland of the National Society for the Prevention of Cruelty to Children. Your Council has already recorded on the minutes its thanks to these gentlemen for their services.

Hon. Treasurer's Statement.

Mr. Riddell, the Hon. Treasurer, will submit his Statement of Accounts. He has had some heavy expenditure to meet owing to the appearance of dry-rot and insect attack in the upper part of the building. Your Council feels that as long as Mr. Riddell continues to be Hon. Treasurer the financial interests of the Society will be carefully watched.

Exchanges.

Your Council continues to receive publications from leading Institutions and Societies in exchange for this Society's Proceedings, many of those received being of great importance. A list appears on pages 89 to 91.

Council's Thanks.

The Council wish to place on record its thanks to the Press for the full reports of the Society's work from time to time. The Council's thanks are also due to the Lecturers for their assistance during the session.

Election.

Three members of the Council retire from office, all of whom are eligible for re-election, and the meeting will be asked to fill the vacancies, as well as that caused by the lamented death of Mr. Horner already referred to by the President.

Treasurer's Statement.

Mr. Henry Riddell, Hon. Treasurer, presented the financial statement, which showed a reduction of £86 in the adverse balance, not including £21 deposited with the Treasurer by the Archaeological Section. He thought that in the present year they would be able to wipe out completely their debt, and urged upon all members to make an effort to increase the membership under the new subscription scheme.

Election of Council for 1919-1920.

Moved by Couucillor Henry Riddell, seconded by Mr. J. M. Finnegan :—

Resolved :—That the three retiring members of the Council,

namely, Sir John Byers, Dr. Allworthy, and Mr. William Faren, be re-elected, and that the names of Sir Charles Brett and Mr. Arthur Deane be added to the list.

Subsequently a meeting of the new Council was held, to elect officers for the ensuing year. These, together with the new Council, will be found on page 92.

ARCHAEOLOGICAL SECTION.

Annual Meeting.

The third General Meeting of the Section was held in the Museum on Wednesday, November 26th, at 3-30 p.m. In the unavoidable absence of the Chairman, Sir Charles Brett, the chair was occupied by Mr. R. M. Young, M.A., M.R.I.A.

The Hon. Treasurer (Councillor Henry Riddell. M.E.), reported that at the close of the session he had funds in hand amounting to almost £64 ; about £6 was due to be paid, and the subscriptions due for the new session and subsidy from the parent society would bring the amount available for the work of the Section during the coming session to about £90.

The Hon. Secretary of the Section (Mr. H. C. Lawlor, M.R.I.A.) reported that from various causes three members of the Section had resigned, and one, the late and much lamented Mr. John Horner, had died ; four new members had joined, leaving the membership of the Section at 69. He expressed regret that during the past session a more general interest in the objects of the Archaeological Section had not been shown, and that no applications for grants in aid of research had been made by members or others since last meeting. He read an account of the investigation of the crannog at Ballygolan (adjoining the Bellevue Gardens, Antrim Road, Belfast), and of some megalithic monuments in the sandhills at Portrush. (For details see pp. 71—86.)

Mr. W. A. Green exhibited some interesting pottery frag-

ments, bones, and rude flint implements found by him in a newly discovered sandhill settlement at Portrush.

The office-bearers for the new session were elected as follows :—

Chairman,	Sir Charles Brett.
Hon. Treasurer,	Mr. Henry Riddell, M.E., M.I.M.E.
Hon. Secretary.	Mr. Henry C. Lawlor, M.R.I.A.

Executive Committee, in addition to the foregoing (ex-officio)—Professor Gregg Wilson, D.Sc., Mr. Arthur Deane; (elected) Mr. R. S. Lepper, M.A., F.R.Hist. Soc., Mr. Alec Wilson, J.P., M.R.I.A., Mr. W. B. Burrowes, Mr. T. Edens Osborne, Mr. John Stevenson, the Rev. William Adams, M.A., Mr. Fergus Greeves, Mr. Robert May.

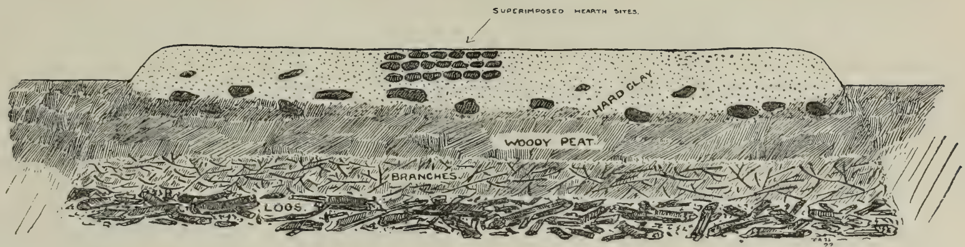
The Hon. Secretary of the Section, Mr. H. C. Lawlor, read the following reports :—

I.—INVESTIGATION OF CRANNOG IN THE TOWNLAND OF BALLYGOLAN.

At the extreme north-west corner of the townland of Ballygolan (the place of the forked streamlet) is a saucer shaped, somewhat marshy hollow in which rises a prolific spring. A channel cut to carry away the water from the spring has drained the hollow where once was a deep lake. A natural ridge of gravel soil retained the water of the lake on its eastern side, while on its western side the steep slopes of the Cavehill and Colin Ward begin to rise.

The farm in which the site of this ancient lake is situated is now known as Hazelwood and is bounded on its eastern side by the Antrim Road and on its northern side by the Bellevue Gardens.

A little to the east of the centre of the hollow is a circular knoll some four feet higher than the surrounding ground, seventy across at its base, sixty at the summit. The knoll is flat topped, and no foss or vallum surround it as in the great majority of raths.



SCALE $\frac{1}{8}$' = 1ft.

SECTION OF CRANNOG AT BALLYGOLAN, CO. ANTRIM

The present proprietor of Hazelwood—Mr. Read, readily gave his consent to the investigation of the mound, which was carried out during Easter week of this year. I had the assistance of five men the first day and three the two following days. We decided first to search for the remains of a refuse deposit or kitchen midden outside the mound, and with this object in view dug a deep trench round the base of the mound, examining carefully all the soil thrown out. It is of ordinary peat. At a depth of six feet we had to suspend operations in this direction owing to the inflow of water, but we probed down the soft bottom of the trench with crowbars, and found that the peat extended down at least four feet further, so that the growth of peat is not less than, and probably more than, ten feet. In probing we did not come to hard till, so that the original depth of the lake was not ascertained. The section of the trench showed that the mound had been built after the usual manner of early lake dwellings. As a foundation, large logs and branches of trees were laid down, weighted down by stones and soil. When the pile had been thus raised above the water level, it became a habitable island. The timber branches upon which the crannog was built are quite rotten and of a soft sponge like texture: they consisted of hazel, birch, oak and fir. I saw no sign of upright stakes surrounding the mound as are usually found in lake dwellings; the branches and logs on which the island was built seem to have been thrown down horizontally in haphazard fashion.

In the circular trench we found no remains of implements or utensils; as we could not dig deeper than six feet on account of the inflow of water, we filled in the trench and re-sodded it.

We next proceeded to cut sectional trenches and pits in the mound itself. The upper surface of the island is composed of clay soil of a depth of about three feet or more in places. Near the centre of the island we came upon three distinct hearths, one above the other, with clay intervening. It is evident these represent three periods, and that the lowest hearth represents

the earliest period of occupation. As the foundations of the island rotted and sank, the inhabitants found it necessary to build the island higher by adding another course of clay, with new hearths on top of the older. At a later period, a further sinking of the foundation made another floor necessary, apparently the last one in the history of the lake dwelling.

Ashes, burned fragments of wood and bones, were numerous in the immediate vicinity of the three hearths, and here and at the various places where we excavated were found a considerable number of fragments of broken pottery cooking vessels. It is worthy of remark that these pottery fragments were all found fairly near the surface, not at the level of the lowest stratum of occupation. The pottery is all of that distinct type which I have in former papers described as souterrain pottery, and not of the type usually found in crannogs. None of it showed signs of having been turned on a wheel, though some of it had thumbnail ornamentation.

A few years ago Mr. F. J. Bigger made some slight excavations in the form of small trenches in this crannog, and found some small fragments of the same pots, which he presented to the City Museum. These and what we found are exhibited together.

Mr. Bigger, in a short account of his investigation (published in the *Ulster Journal of Archaeology*, 2nd Series, Vol, VII, p. 195) states that he also found a "Danes pipe" which, with the pottery fragments, he had presented to the Public Museum. The records of the City Museum show that the pottery was given, but no pipe, and I am inclined to be sceptical about the latter. Mr. Bigger makes the extraordinary error of describing this crannog as a Dun.

In our investigation we found no implements or fragments of metal of any sort, and no flints; we found a stone implement, a flat oval, measuring $5\frac{1}{2}'' \times 4\frac{1}{4}'' \times 2''$, slightly hollowed in the centre of each face and chipped at the edges. I cannot suggest for what purpose this implement served.

From conclusions arrived at in former papers in investi-

gations in connection with souterrains, I think we may be safe in dating the pottery about the fifth or sixth century, and that the upper floor or stratum of the crannog is of this date; no evidence was forthcoming as to the possible age of the lower strata or of the original date of the construction of the island.

Our investigations were not by any means exhaustive, and a further and more complete examination might produce interesting results.

II.—SOME MEGALITHIC MONUMENTS IN THE PORTRUSH SANDHILLS.

Some years ago my friend, the late Mr W. H. Patterson, wrote me when I was staying in Portrush asking me to inspect a megalithic monument of the type usually called a Giant's Grave, situated at a spot he described in the Sandhills, but which was not marked in the Ordnance Survey Map.

I proceeded to the place indicated, but could find no trace of the object of my search. Enquiry from some of the golf green attendants, however, elucidated the reason of my want of success.

When the golf course was being made some thirty years ago, the giant's grave was found to be an impediment in laying out one of the greens, and the committee ordered its destruction. The larger stones were blasted in pieces and carted into Portrush for building purposes, and the smaller ones covered over to level up the surface of the green. My informant told me he had been one of the men employed to carry out the work.

I reported the matter to Mr. Patterson, who replied saying that fortunately he had preserved a carefully made plan, drawn to scale, of the grave as it was when he visited it many years before. He sent me the plan with a pencil sketch, asking me to lay them before this society to be recorded, if possible, in one of our publications. I now have pleasure in placing Mr. Patterson's plan and sketch before the archaeological section in the hope that his request may be acceeded to. (Sketch No. 1).

PLAN OF MEGALITHIC MONUMENT IN PORTRUSH SANDHILLS, CO. ANTRIM.

FROM ROUGH SKETCH MADE BY THE LATE W. H. PATTERSON. M.R.I.A. (No. 1)

As accurately as I can ascertain the position of the grave on the ordnance map, it should have been placed at a point $1\frac{1}{2}''$ W.N.W. of the letter *B* in the name of the townland of Ballycraig Lower, on sheet No. 6, County Antrim.

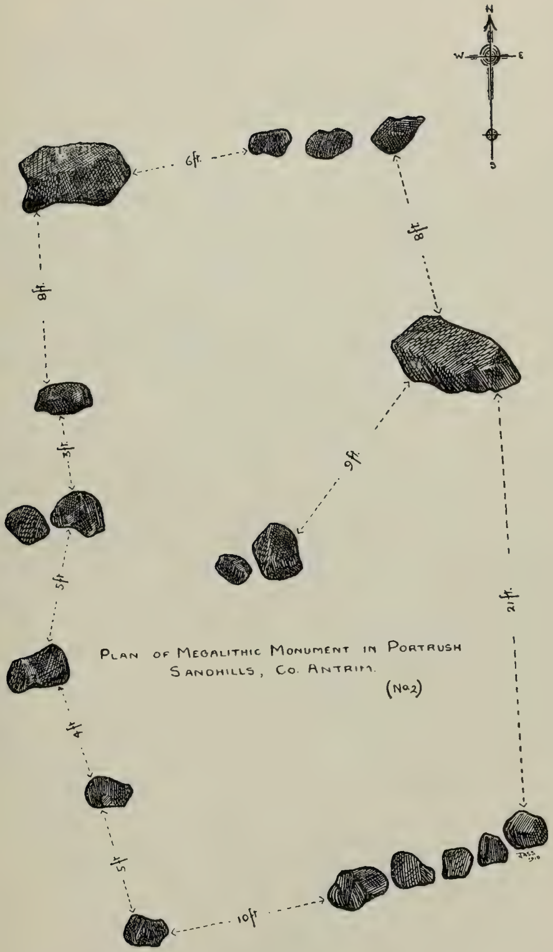
Last summer, when again visiting Portrush, I was pointed out by a resident, Mr. Gaston, of The Warren House, another somewhat similar though smaller monument at a point on the map approximately $2\frac{1}{2}''$ north of the second *A* in the same townland name. The stones of which I show a roughly measured plan (No. 2) are in a low lying part of the sandhills on a grass covered knoll about 3 feet higher than the immediately surrounding ground.

With one exception the stones, of which there were 18, did not present any notable features, being ordinary basalt field stones of no great size ; the one exception being an elongated rough pillar stone, in one side of which is a round cup-shaped hole about two inches across and $1\frac{1}{2}''$ deep. I could not decide if this hole was artificial or the work of nature.

With the aid of three men, Mr. Gaston and I made considerable excavations in the knoll. We found that its foundation rested on an old raised beach of white limestone gravel, into which we penetrated some depth. At no point in our excavations did we find any trace of burned wood, bones or other remains which would indicate that the knoll had ever been used either as a place of burial or human occupation.

With our knowledge of the shifting nature of sand in these hills, it seems most extraordinary that the stones were all at the surface, none being entirely buried. This fact would seem to suggest that the stones could not have lain there for the number of years usually attributed to monuments of the type to which this one has the appearance of belonging.

While not prepared to assert positively that the stones are, or are not the remains of a monument of great antiquity, as they are locally regarded, I think it right to suggest that they may have been placed there in comparatively modern times as a base



PLAN OF MEGALITHIC MONUMENT IN PORTRUSH SANDHILLS, CO. ANTRIM. (No. 2)

SCALE $\frac{1}{4}'' = 1$ft.

on which to lay boards or branches of trees on which one or more hay stacks might have been piled.

At a point, which on the map would be approximately one inch north of the letter *I* in the same townland name of Ballycraig Lower, I found on an eminence on the east bank of a small stream which flows and eventually sinks into the sandhills, another knoll through the surface of which appear the tops of several apparently large stones. With the negative results of the foregoing investigation in mind, I did not feel warranted in making excavations on the spot, but I wish to take the present opportunity of placing on record the existence of these three monuments of antiquity in case others should like to pursue their examination more fully.

EDUCATIONAL ENDOWMENTS (IRELAND) ACTS, 1885.

The Accounts of the Belfast Natural History and Philosophical Society for the year ended 30th June, 1919.

Dr. | **Cr.**

CHARGE.

	£ s. d.	£ s. d.
To Subscriptions		£103 15 0
,, Dividends		27 17 2
,, Rents		150 0 0

LIST OF SECURITIES.

$4\frac{1}{2}$ per cent. Debentures York St. Flax Spinning Co.	400 0 0	
5 per cent. War Loan, 1928-47	305 5 3	
Balance against Account on 31st July, 1919		88 16 1
Balance, per Bank Book, 30th June, 1919 .. 96 14 0		
Less Lodgments after close .. 44 18 0	51 16 0	
Add Cheques drawn after close	37 0 1	
Net Balance, Dr.	£88 16 1	
Total,		£370 7 3

DISCHARGE.

	£ s. d.	£ s. d.
By Balance as per last Account		£195 11 10
,, Maintenance of Premises, &c.		38 0 3
,, Rent, Rates and Taxes		34 11 6
,, Salaries—Allowances to Assistant Secretaries		20 0 0
,, Printing and Stationery		11 1 0
,, Advertisement		9 18 4
,, Postage and Carriage		9 16 4
,, By other Payments, viz:—		
Expenses of Lectures	£13 5 0	
Lanterns, &c.	6 10 0	
Cheque Book	0 8 4	
Audit Fee	1 1 0	
Gas Repairs	0 3 0	
Exploration Expenses	13 4 0	
Collecting Subscriptions, &c.	7 12 8	
Interest to Bank	9 5 0	
		51 9 0
Total,		£370 8 5

We certify that the above is a true Account.

ROBERT M. YOUNG, *Governor.*
HENRY RIDDELL, *Accounting Officer.*
21st day of August, 1919.

I certify that the foregoing Account is correct.

A. A. FLYNN, *Auditor.*
9th day of October, 1919.

The account of the Belfast Natural History and Philosophical Society given on preceding page is in the form prescribed by the Local Government Board. It includes the subscriptions and expenses of the Archaeological Section, separate account for which now follow.

INCOME AND EXPENDITURE ACCOUNT TO JUNE 30th, 1919.

ARCHAEOLOGICAL SECTION.

	£	s.	d.
June, 1918—Balance in funds of Belfast Natural History and Philosophical Society ...	£42	12	10
,, 1919—Subscriptions	17	3	0
Do. last year's account ...	0	11	0
Subsidy from Parent Society ...	12	0	0
	£72	6	10

	£	s.	d.
June, 1919—Cost of Collections 1917-18 and 1918-19	£3	14	5
Stamps, &c.	0	8	9
Two years' audit fee	0	14	0
Rubber Stamp and Pad	0	4	10
Minute Book	0	6	0
Mayne, Boyd & Co., Printing, &c. ...	2	12	0
Rent of Meeting Room	0	8	0
Balance in funds of Parent Society ...	63	18	10
	£72	6	10

EXCHANGES.

AUCKLAND—Annual Report of the Auckland Institute and Museum. 1918-19.

BARCELONA—Publications of Barcelona Museum.

BELFAST—Proceedings of the Belfast Naturalists' Field Club. 1918-19.

BERGEN (NORWAY)—Publications of the Bergen Museum.

BIRMINGHAM—Proceedings of the Birmingham Natural History and Philosophical Society. 1918.

BRIGHTON—Annual Report of the Brighton and Hove Natural History and Philosophical Society. 1918.

CALCUTTA—Bibliography of Indian Geology. Part I and II.

,, Records of the Geological Survey of India.

,, Report of the Progress of Agriculture in India. 1917-18.

CAMBRIDGE (U.S.A.)—Bulletin of the Cambridge Museum of Comparative Zoology.

CAMBRIDGE—Proceedings of the Cambridge Philosophical Society.

EDINBURGH—Proceedings of the Royal Society of Edinburgh. 1917-18.

,, Transactions and Proceedings of the Botanical Society of Edinburgh.

,, Notes from the Royal Botanic Gardens, Edinburgh.

ESSEX—The Essex Naturalist. Vols. VIII.—XIX.

HALIFAX—Proceedings and Transactions of the Nova Scotian Institute of Science.

INDIANA—Proceedings of the Indiana Academy of Sciences, 1916-17.

LIMA (PERU)—Boletin del Cuerpo de de Ingenieros de Minas del Peru.

LONDON—British Museum, Economic Publications.

LONDON—Quarterly Journal of the Royal Microscopic Society.
,, Memoirs of the Royal Astronomical Society.
,, Quarterly Journal of the Geological Society.
,, Report of the British Association. 1918.
LOUSANNE—Bulletin de la Societe Vaudoise des Sciences Naturelles.
MASSACHUSETTS—Bulletin of the Museum of Comparative Zoology.
MELBOURNE—Proceedings of the Royal Society of Victoria.
MEXICO—Anales del Instituto Geologico de Mexico.
NEW HAVEN—Transactions of the Connecticut Academy of Art and Sciences. 1917.
NEW ORLEANS—Sixth Biennial Report of the Board of Curators of the Louisiana State Museum. 1917-18.
NEW YORK—The Geographical Review. Monthly.
NOTTINGHAM—Annual Reports, Nottingham Naturalists' Society, 1913-1918.
OHIO—Bibliographical Contributions from the Lloyd Library.
,, The Ohio Journal of Science.
OTTAWA—Memoirs of the Canadian Geological Survey.
,, Memoirs of the Geological Survey of Canada, Department of Mines.
PHILADELPHIA—Proceedings of the Academy of Natural Sciences of Philadelphia.
,, Proceedings of the American Philosophical Society.
PUSA (INDIA)—Scientific Reports of the Agricultural Research Institute. 1916-17.
RIO de JANEIRO—Report of the National Museum of Brazil.
SAN FRANCISCO—Proceedings of the California Academy of Science.
STAVANGER (NORWAY)—Report of the Stavanger Museum. 1917.
STIRLING—Transactions of the Stirling Natural History and Archaeological Society. 1914-1919.
ST. LOUIS—Public Library Monthly Bulletin.

ST. LEONARDS—Report of the Hastings and St. Leonards Natural History Society. 1917-18.

TORQUAY—Journal of Torquay Natural History Society.

TORONTO—Transactions of the Royal Canadian Institute.

UPSALA—Bulletin of the Geological Institution of Upsala University.

WASHINGTON—Annual Report of the Smithsonian Institution.

" Annual Report of the United States National Museum.

" Bulletins of the Bureau of American Ethnology.

" Bulletins of the Smithsonian Institution.

" Contributions from the United States National Herbarium.

" Proceedings of the United States National Museum.

" Smithsonian Institution Miscellaneous Collections.

" Year Book of the United States Department of Agriculture. 1918.

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BELFAST
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THE NORTH OF IRELAND DURING THE GLACIAL PERIOD.

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Lecturer in Geology, Queen's University, Belfast.

FLUCTUATIONS IN THE FOREIGN EXCHANGES.

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11th November, 1919.

Councillor Henry Riddell, M.E., M.I.M.E., in the Chair.

THE NORTH OF IRELAND DURING THE GLACIAL PERIOD.

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(*Abstract*).

The subject was introduced by a description of the traces left by the passage of ice-sheets over a country.

The scratches and grooves impressed upon rock surfaces were illustrated and their importance as records of the direction of movement was discussed.

The deposits formed by glaciers next received attention, and these were divided into (*a*) Boulder Clay, an unstratified clay with striated stones, many foreign to the district in which they now rest; and (*b*) stratified clays, sands and gravels accumulated by the action of the running water associated with ice. The Boulder Clay occurs either in sheets of irregular thickness or in slightly elongated ridges with smooth contours, such as those which are so common in County Down, and known as drumlins. The stratified clays are lake deposits formed in standing water near the ice-margin, and the sands and gravels consist of coarse materials, lying in sheets or fans, accumulated under somewhat similar conditions, or in long tortuous ridges, called Eskers, the product of streams of water flowing in tunnels in or beneath the ice.

Accumulations of clay, stones and sand which are formed along the margins of an ice-lobe, are known as moraines and serve to indicate the limits of the ice at its maximum extension and at various stages of its retreat.

The stones which are carried by the ice for long distances from the parent rock are called Erratics, and serve to indicate

the main direction of ice flow. These are extremely plentiful over the district under consideration, and several, including the Clogh More near Rostrevor, were shown upon the screen.

Attention was next directed to the effect of ice-sheets upon the ordinary drainage of the country, and it was shown that the advance of a glacier might interrupt the normal flow of rivers and cause them to form lakes, which, by their overflow, might cut channels or gorges in the rocks. When the ice had retreated and the lakes been drained, these gorges were left as permanent records of the levels of the water, and consequently of the former position of the ice-front.

In certain cases the overflow stream remained in the temporary channel after the retreat of the ice, thus producing a permanent diversion of the drainage. Examples of this were cited in the case of the Bush River and the streams in Glen Aan and Glen Dun, all in County Antrim.

The lecturer then described his investigations of the glaciation of the North of Ireland and first referred to the distribution of erratics as being the most trustworthy indication of the direction of ice movement. In every assemblage of erratics there were always some of which the origin was difficult or impossible to determine, but there were usually others with such striking characters that they could be identified readily. The most useful of these in the district under consideration were the fine-grained granite of Ailsa Craig in the Firth of Clyde, and the granites and pyroxenic rocks of an area extending from Slieve Gallion in County Tyrone to the neighbourhood of Omagh, while in the immediate neighbourhood of Belfast, the rhyolites which occur at Tardree and at several other places on the Antrim Plateau, were of considerable use.

Some of the more important deposits of Glacial age and the drainage channels and lake-terraces of the district were then described and their bearing on the glaciation of the country was explained.

The conclusions at which the lecturer had arrived as the result of his work in the North of Ireland were as follow :—

(*a*) The district was first glaciated by ice which came down the Firth of Clyde from the Scottish Highlands, over-rode the whole of the Counties of Antrim and Down, extended at least as far inland as the south-west corner of Lough Neagh, and passed over the Mourne and Carlingford Mountains and so into the Irish Sea.

(*b*) At a slightly later stage ice from the mountainous regions to the west and north of Lough Neagh advanced into the lowlands bringing with it boulders of the granites and pyroxenic rocks of the Slieve Gallion area, and gradually pushing back the Scottish ice.

The western ice-sheet passed south eastward across the head of the Belfast valley by way of Moira and Hillsborough, and so out to sea at Newcastle. It formed a continuous sheet away to the south-west as far as the central plain of Ireland.

A portion of the western ice also flowed into Lough Neagh and thence northwards by way of the valley of the Lower Bann as far as Coleraine, but it did not reach the eastern shore of Lough Neagh except in the extreme South, being held up by the Scottish ice, which though in retreat still occupied that part of the area in sufficient force to hold up the flow from the West.

It would thus appear that the Scottish and Western ice-sheets were to some extent contemporaneous, and that no lengthy period elapsed between the two glaciations, as has been held by some geologists.

The lecture was illustrated by lantern-slides, maps and relief models of the Belfast District, and the lecturer answered several interesting questions put by members of the audience. The meeting terminated with a hearty vote of thanks to the lecturer.

21st November, 1919.

The President, Professor Gregg Wilson, in the Chair.

FLUCTUATIONS IN THE FOREIGN EXCHANGES.

By Professor F. T. Lloyd-Dodd, M.A., D.Sc.
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To the ordinary individual the term "Foreign Exchanges," if it conveys any impression at all, merely brings to mind mystic columns of figures which appear periodically in the morning newspaper. If his curiosity is still unsatisfied, he may turn up the reference in the Encyclopaedia Britanica where it is defined as "The system by which commercial nations discharge their debt to each other." Having read that, he feels that he knows all that is worth knowing on the subject.

There is, however, a great deal more in it than that! Foreign Exchange is admittedly a complex subject, and on the surface is full of appalling pitfalls and intricacies to the unwary. Once one has delved beneath the surface, he finds it an absorbing and fascinating study. For those who have not either time or inclination to study the subject deeply, it is possible, with little difficulty, to grasp the principle on which foreign exchange is based, so as to take an intelligent interest in exchange fluctuations.

Stated briefiy, foreign exchange is the buying and selling of the money of other countries. From our point of view, foreign exchange is the business of exchanging foreign money into English money; and we would naturally expect that the exchange would be carried out at a fixed ratio of so many dollars or francs for a sovereign. But this is by no means the case. Money is a commodity, and like other commodities is subject to the law of supply and demand. If there is a large supply of foreign money for sale, with a small demand, the price goes down. If on the other hand there is a small supply and a large demand, the price rises.

It is necessary for us to grasp, therefore, two things—(1) the degree of intrinsic value that lies behind the currencies of different countries ; and (2) the causes of the fluctuations in the demand and supply of foreign money, which result in the fluctations of the Foreign Exchanges.

With regard to the first, we find on examination that we can group the currencies of the commercial countries of the world into five classes :—

1. Under the English system money carries the right of being immediately turned into gold. In the United Kingdom sovereigns are legal tender up to any amount, as are also Bank of England notes. Bank of Ireland notes are legal tender in Ireland only. Silver and copper are only token money, silver being legal tender up to 40/- and copper up to 1/-. If a Bank of England note is presented to that Bank, it cannot meet it with another note, but must pay sovereigns against it. So that normally all the money we use, except our small change, consists either of gold or of paper that can be unquestionably turned into gold. I used the word *normally* because the use of Currency Notes as a temporary war measure is a deviation from the usual system.

2. In the second class we may place the currencies of the so-called gold standard countries, under which money can be converted into gold when it is convenient to the Central banks of these countries. German currency is an example of this class. In theory the notes of the Reichsbank can be turned into gold on demand. In practice they cannot except when it is convenient to Germany. In France the Bank of France can meet its notes in five franc pieces. In the United States "gold certificates" can be turned into gold, but there is an enormous amount of American paper money which does not possess this right, while silver dollars are legal tender up to any amount. The American banks keep the gold certificates in hand as far as possible, and meet demands on them in other forms of legal tender. So that if it does not suit the convenience of American bankers to permit gold to leave the country, they can practically refuse it, and still meet their legal obligations.

3. Thirdly, there are certain countries such as India, Japan, Mexico, Brazil, and the Argentine, which have a semi-gold standard They will issue silver or paper currency *against* gold, but have no obligations to convert the silver or paper currency *into* gold on demand. Such countries usually take measures to keep the exchange value of their currency at or near the legal ratio. Thus India maintains balances in London, so that the Government can supply English money, when the demand for it in India becomes so great, as to depress the purchasing power of the rupee to too great an extent.

4. Fourthly, there are the few silver standard countries of which China is the only important example, and lastly,

5. There are the few purely paper money countries where gold is simply dealt with as ordinary merchandise, and always stands at a premium.

We see then that the intrinsic value behind the currencies of different countries varies considerably. Gold is the international medium of exchange—acceptable everywhere—and while the notes of a country are perfectly serviceable in *that* country, they are useless for international trade. It is for this reason that the gold-backing of a country's currency has such an important influence on its foreign exchange.

Having considered thus briefly the money of different countries, which is the subject matter of the Foreign Exchanges, we must now see how demand for the money of one country arises in another. A claim for money between nations arises in exactly the same way as between individuals. An individual may be regarded as exporting the services, which he renders, in his business or profession, and for which he is paid in money. He imports the food, shelter, clothing, amusements, and all the luxuries and necessaries of life which he enjoys, and pays for them by cheque or cash. At the end of the year, if he has kept careful accounts, he can see what he has received, how he has spent it, and the exact amount of his balance, or overdraft, as the case may be.

The matter is more complicated in the case of nations. In any individual pair of trading nations, there are at any time hundreds of individuals buying and selling commodities and services, which it is difficult to record. It is this very difficulty of tracing the exchange of goods and services which is part of the fascination of the study of foreign exchange. The most carefully compiled records of a nation's income and expenditure always leaves a margin of what must be, at the best, estimated statistics. The monthly returns of the Board of Trade give us the figures of our exports and imports, and these figures, though as accurate as they possibly can be made, yet for various causes leave a margin of error. These figures, in hundreds of thousands, for 1913. were :—

1913.		Food, Drink & Tobacco.	Raw Material	Manufactured Articles
Imports	...	2,902	2,818	1,930
Exports	...	326	699	4,114

Taking the totals, and allowing for the re-export of foreign and colonial produce, we find that for that year our imports, which are much larger in the case of England than in that of any other country, exceeded our exports by £133,900,000. This huge excess of imports is at first sight alarming. It forms what the older economists would have called an adverse balance of trade, and in their view would indicate that the country was rapidly approaching bankruptcy. Two explanations at once present themselves. In 1913, we either received goods worth roughly 134 millions more in value than the goods we gave in exchange—the difference being clear profit—or we paid for the difference in gold. The first explanation, if true, would be very comforting, but unfortunately the other countries have not conspired to kill us with kindness and to give us £134,000,000 worth of goods for nothing. Nor did we pay this difference in gold, for the Board of Trade returns show that we imported rather more bullion than we exported. A third and more serious explanation then presents itself—that the balance was not paid

for, but owed. In this case we would be exporting promises to pay, which would mean that we were either raising loans abroad or that other nations were investing in our securities. Though it is difficult to get accurate figures, yet there can be no doubt that in 1913 our income from foreign securities was much greater, on balance, than the amount paid out to foreigners holding our securities. Sir George Paish, the editor of the "Statist," whose figures are usually exceedingly accurate, calculated that about that period we were actually increasing our holding of foreign and colonial securities at the rate of about 160 million pounds a year. The third explanation, therefore, falls to the ground.

It is evident then, that there must be some other explanation of the excess of imports, and the matter looks less alarming when we find that most other nations also import more than they export. The real explanation lies in the fact that the mutual relations of nations, particularly when the intercourse is of long standing, is not all comprised in the actual exchange of commodities. Exports and imports are but one element, though a very important one, in the sum total of the commercial transactions. In order to understand the exact position of a country, we must consider not merely the equation of reciprocal demand, but rather the equation of indebtedness between countries. It is not equivalence of exports and imports that constitutes a stable condition in trade, but the equivalence in the sum of debts due *to* a country and that of debts due *by* it. In examining this equation of indebtedness we are simply considering the various Debtor and Creditor items in a country's balance sheet. These items may best be arranged in the following order :—

1. To Exports and Imports, formerly considered the sole items of the balance sheet, we may give the first place. A country is clearly Dr. to other countries for the value of its imports, and Cr. to other countries for the value of its Exports.

2. Next a country is Cr. for all services done by its ships and traders to other countries. Ships employed in carrying for

foreigners are what is called an invisible export, and might almost be classed under the first head. On the other hand a country is Dr. for services rendered it by foreign ships and traders. When we consider that Britain in 1913 did about one-half of the ocean carrying trade of the world, the importance of this item can be realised.

3. The third item on the balance sheet is loans and investments. Almost every country in the world is a borrower or a lender. When a country contracts a loan, the lending country is Dr. for the time being until the loan is carried out, and the borrower is paid. The borrower exports securities or promises to pay, and imports in return the goods or services required.

4. The annual Interest on Capital already invested acts in the opposite direction. The Investing Country is Cr. and the Borrowing Country Dr. We may regard the lender as exporting "Coupons" and the borrower has to export goods to meet them.

5. Repayment of a loan previously incurred acts in the same way as interest on the loan while outstanding. The receiving country is Cr. and the repaying country Dr. We may take it generally that young countries, such as Canada which have not yet fully developed their railways, towns, and lands, are borrowers, while older countries, with accumulated capital are lenders.

6. The next item is a minor one compared with those mentioned, but it still makes a considerable aggregate amount. A country is Cr. for the earnings of its native merchants residing abroad, so far as they are transmitted home. It is, of course, in turn Dr. for the earnings of foreigners residing in the country. It is scarcely necessary to separate from this item, the case of foreigners or natives resident abroad transmitting money for benevolent purposes. We have a good example of this in the remittances sent home from Irish emigrants in U.S.A. and elsewhere.

7. The expenditure of a nation's Government abroad, or of its citizens travelling abroad, renders a country Dr. for such

expenditure, and conversely it is Cr. for the expenditure of other governments or of foreigners inside its territory—that is, of course, as far as they derive their power of expenditure from their native country.

8. Another type of international payment which is of special interest at the present time is that of tribute or indemnity payable by one country to another. The paying country is Dr. and its receiving country is Cr. for such payments. Last of all we may include a streamlet, which sometimes swells into a respectable torrent, in the money carried with them by emigrants and the amounts sent yearly to "remittance men" and other undesirables. Of exactly the same nature is the drain of money caused by the wealthy American heiresses who marry English and European husbands, and draw yearly, large sums from the United States as dowries. This "dowry drain," as it has been called, makes a fairly serious item in the American balance sheet.

Such then are the principal, but by no means the only items that determine the balance of indebtedness. It is important to fix the attention on the cardinal fact that the equation of indebtedness is the condition to be satisfied in all solvent trade. Equivalence of exports and imports may or may not exist. There is no advantage or disadvantage in excess of either. A country may be prosperous or the reverse in either case, but these are of importance, because in general the exports and imports are the most easily altered items in the account, and an adjustment in the balance of indebtedness will take place through them. An unfavourable balance will be discharged, in most cases, by a reduction of imports or by an increase of exports, or by a combination of both processes.

We have now to consider in what manner the indebtedness created through the several elements named is discharged. There are several alternative methods. Payments may be made in gold, or commodities to the value of the debt may be shipped. In practice, however, we find that debts are discharged by means of

Bills—Foreign Bills of Exchange. Let us take a very simple example to illustrate the manner in which this is effected—

$$\begin{array}{ccc} \text{LONDON.} & & \text{PARIS.} \\ A & \longrightarrow & B \\ \downarrow & & \uparrow \\ D & \longleftarrow & C \end{array}$$

Suppose a merchant "A" in London buys goods value £500 from a merchant "B" in Paris; and suppose another man "C" in Paris buys goods worth £500 from "D" in London. "B" now draws a Bill of Exchange on "A" for £500, and sells it to "C." "C" transmits the Bill to "D" in settlement of his account, and "A" pays "D" the amount on presentation. Thus two transactions are settled by the one Bill of Exchange without the necessity of shipping gold from one country to the other.

In this example we have presumed individual traders, but individuals may be taken as types of classes. The relations between these classes are carried out by intermediate dealers who make foreign exchanges their special business. The exporter of commodities sells his Bill to a broker, who in turn sells it to an importer for the purpose of being transmitted to a foreign country in payment for goods.

So far we have only noted the principle of indebtedness, but other complicating circumstances are at work. Bills are drawn hourly, for different periods of time, by persons of varying degrees of credit, and as a necessary consequence these influences are shown in the market price of Bills. Again, each country has its own peculiar currency system, so there is the necessity of measuring the value of a Bill expressed in one currency in terms of another. This difference of currencies is perplexing, and renders calculations more difficult, but it does not create the system of foreign exchange, which arises from the principle of indebtedness and the cost of transmitting money from one place to another.

Owing to the difference in currencies we require a fixed standard or ratio to enable us to express money of one country in

terms of the money of another. This ratio is called the "Mint Par of Exchange," and depends on the intrinsic value of the currency. The value of the currency unit is taken to depend on the quantity of pure metal it contains as fixed by law, and the mint par tells us how much of the currency of the other country contains the identical quantity of the same pure metal. Thus, for example, the value of 2,000 new sovereigns is legally the same as the value of the gold in 2,522 Napoleons, which gives us the value of £1 0s. 0d. = 25·22 francs, and this is the French Mint par of Exchange. In the same way the United States Mint par is £1 = 4·86 dollars, The importance of the Mint par lies in the fact that as the exchange frequently fluctuates above or below par, we can only tell whether the rate is for or against us by knowing the par, which is the centre about which it oscillates.

The rate of exchange is very seldom at par, but rises above or falls below it, according to the variation in the demand and supply of bills. These varying rates in the currency of one country which may be obtained for a fixed amount in the currency of another form is what is called the Course of Exchange. Or putting it more simply, the Course of Exchange is the price list at which Bills of Exchange on different countries are selling at a particular time. The first thing that strikes one about the Course of Exchange as published in the daily papers, is the fact that most of the quotations are in foreign money, expressing the amount of foreign money payable, at the current rate, for one sovereign. This arises from the fact that the bulk of our transactions are settled by Bills drawn abroad. Owing to the magnitude of our trade, the stability of our currency in normal times, the facility with which credit could be obtained there and other contributing causes, London became the settling place of Europe and the world; and the seller of a good Bill on London is always sure of a buyer at a good price. The foreign importer, too, would rather pay for imports by remitting, than by allowing us to draw on him, because the price to be paid depends partly on his own success in bargaining. This arrangement also seems

to suit our merchants, because the drawing and negotiating of a foreign Bill requires a knowledge of the Exchanges which they do not always possess. As a result the settlement of our foreign trade is largely effected by Bills of Exchange which are drawn and negotiated abroad, and accepted and paid in London.

This adds a further complication, because it is necessary to view the Exchange from the foreign standpoint. An increase of price is not usually desired by the buyer of an article, but in the case of the foreign exchanges an increase in the rate means that more foreign money is given for a sovereign.

In the example which we took the debts were equal and exchange would be at par, but what if they are admittedly unequal? What happens if more bills are wanted than are offered for sale? Naturally the price rises. As buyers find that there are not enough bills to go round, they bid against one another, and the price goes to a premium. As soon as the price advances sufficiently other means of remittance become available in the form of Bankers' Drafts. If the demand still continues, the balances on which the banker draws become exhausted, so he must find some way of covering his draft by remittance. What he does is to buy bills on other countries, send them to his correspondents there, and request that they will remit for his account in London. So long as suitable bills on other countries are obtainable, the rise in the London rate will be held in check, but as they grow scarcer the price must rise, with the result that the Exchanges of other countries are set moving in the same direction. The general rule of European exchange movements is that the exchanges all rise together or fall together. If the demand for Bills on London continues, the cost of covering drafts increases, and finally we reach the stage when it is cheaper to send gold than to buy Bills of Exchange. This point is called the Export Gold Point, and for France is 25·32. A Gold Point is simply the point above or below the par of Exchange at which it becomes cheaper to remit gold, paying the cost of carriage and insurance, than to buy Bills of Exchange.

Once the circumstances of a rise in the exchanges are clearly understood, those of a fall present no difficulty. Slackening of demand or increase of supply forces down the price. The drop is limited by the anxiety of exchange dealers to pick up bargains. If the drop is continuous, we arrive at the opposite extreme when London paper becomes so cheap that it pays to use it to buy gold at the Bank of England and transmit it to France. The rate at which this will happen for France is 25·12, which is called the Import Gold Point.

Many economists would have us believe that the Gold Points are fixed, and that the rate of exchange cannot rise or fall beyond the Gold Points without a movement in gold. In practice however this is not so. The Gold export point for Germany is theoretically 20 Marks 48 pfennings. In 1907 the Exchange touched 20 Marks 60 pfennings, and in November 1912 stood for some weeks about 20 Marks 53 pfennings without in either case any gold being sent to London. And the same thing occurs occasionally in other countries, which is simply an illustration of the power of the State Banks to prevent export of gold when it is not convenient.

The ordinary rate of exchange, then, simply depends on the balance of indebtedness between countries, and rises and falls according to the demand for Bills. In certain of the Exchanges this is subject to seasonal fluctuations. Thus in the case of the United States there are usually large amounts owing to it in the autumn, when cotton and cereals are shipped and sold abroad. At other times of the year it usually has to make remittances to meet the interest on foreign loans and investments. As a result there is a regular ebb and flow in the fluctuations, and during the last five months of the year the Exchange is in favour of America, and against it in the first seven.

Apart from such seasonal fluctuations the rise or fall of the rate of exchange presents a problem which is difficult to solve. A rate of exchange is the combined result of a variety of facts and forces, which are so complex and so numerous, as to render

it difficult for us to measure exactly the influence of each. In most cases the best explanation we can give of an exchange movement, is to settle upon one or perhaps two prominent causes which we know to be at work, and to theorize about the remainder. The question turns on the interaction of supply and demand, and I would like to remind you here that it must be viewed from the foreign standpoint. So far as our exchange is concerned it is the supply of bills drawn *on London*, as compared with the demand for such bills, that controls the rate of exchange. These bills mainly arise from (*a*) Trade Transactions (*b*) Stock Exchange Transactions and (*c*) Banking Transactions. Bills are drawn on London against our trade imports, against securities owned by foreigners and sold in London, or securities bought abroad by Englishmen; against loans made to foreign Governments, railways or companies, and interest on money borrowed abroad; against bankers' credits; and for arbitrage and speculative transactions. The greater the supply of these bills, the more the exchange moves against us. On the other hand, there is a demand for these bills by foreigners, in order to pay for our exports of goods to them, for freight, brokerage, and commission; for securities bought in London for foreign account or sold abroad for London account; for interest on loans, and dividends on foreign securities held here; for the creation of new bank credits or to cover drafts; to pay for arbitrage and speculative transactions, and for investments. The greater the demand for bills to make such payments, the more the exchange will move in our favour. You can see, however, that with such a variety of payments outwards and inwards, and with such a complexity of influences on supply and demand, it is difficult always, and sometimes impossible, to account accurately for the fluctuations in the Foreign Exchange.

One other influence on the rate of exchange should be noticed, and that is the Discount Rate. A low rate of discount in this country, as compared with that prevailing abroad will set the Exchanges moving against us; whereas a comparatively high

rate influences them in our favour. We may divide all bills roughly into two classes—Finance Bills and Commercial Bills. Both of these classes are affected by the Discount Rate, but of the two, Finance Bills respond more rapidly, and to a greater extent, to alterations in the Rate than do Commercial Bills. If we take the simple form of a Finance Bill—that made by an operator abroad who wishes to raise money, and does so by drawing on a correspondent here, and selling the draft so created, the cash price he will get for the draft in his local market will depend largely on the current rate of discount here, where the bill is payable. When the London discount rate is comparatively low, finance bills can be drawn on us to greater advantage, and consequently will be drawn in greater volume. A rise in our discount rates will limit, and may temporarily stop, the drawing of such bills. The volume of commercial bills is not so readily influenced, but it *is* influenced all the same by the discount rate. Holders of Bills will wish to secure the extra margin of profit afforded by a low discount rate, and consequently the supply offered for sale increases, with the inevitable result that the price falls. A rise in the discount rate results in bills being held back for better terms, so that the supply on the market is lessened and this moves the exchange in our favour.

I have used the terms "in our favour" and "against us," and these require explanation. The American par of exchange is £1 = \$4·86 that is £100 = \$486, so that we may take it goods worth £100 are equal in value to goods worth \$486. If the exchange stands at 4·87 or 4·88 it is said to be in our favour. But it only favours those who have to make payments in U.S.A., i.e., British Importers,—as they can pay for goods worth \$487 or \$488 instead of for goods worth \$486 only, with £100. It is unfavourable for those who have to receive payments, i.e., British Exporters—because they will receive less than £100 for \$486 worth of goods sold. Again, when the exchange is against us, as at present, importers who have bought \$486 worth of goods have to pay more than £100 for them, while exporters who have sold goods to that amount receive more than £100. Thus an

unfavourable exchange tends to encourage exportation, and discourage importation, and thus automatically adjust the rate of exchange.

The state of the American exchange is engaging the anxious attention of many at present. We have already seen that the par of exchange with U.S.A. is £1 = $4·86. The steady downward movement of the exchange is shown by the following figures:—

1919.	Aug. 1	4·35	Oct.	1	4·18	Nov.	15	4·10½
	„ 15	4·28	„	15	4·18	„	17	4·08½
	Sept. 1	4·19	Nov.	1	4·16¾	„	21	4·04
	„ 15	4·17½	„	8	4·15			

The immediate cause of this drop lies in the recent financial upheavals in Great Britain and the United States. The root cause, however, lies in the balance of indebtedness between the two countries.

Let us compare the balances, at least as far as concerns exports and imports for the years 1913 and 1918.

VALUE OF EXPORTS AND IMPORTS IN £
(00,000 omitted).

Twelve Months ended December 31st.

	Food, Drink and Tobacco.	Raw Materials.	Manufactured Articles.	Total.	Excess of Imports.
1913.					
Imports ...	290,2	281,8	193,0	765,0	133,9
Exports ...	32,6	69,9	411,4	513,9	
1918.					
Imports ...	572,7	458,9	280,2	1,311,8	790,0
Exports ...	12.1	60,8	403,7	476,4	

The contrast between the figures is striking. While our imports in 1918 are almost double the amount of those of 1913, our exports under every heading have decreased. Making allowance for the re-export of foreign and colonial produce, the net result is that while in 1913 our imports exceeded our exports by £133,9 millions, in 1918 the excess of imports was £790 millions. We saw that in 1913 the excess of imports of £1339 millions, represented interest due upon our foreign investments,

and payments for our invisible exports in the services of our ships and banks. During the war the greater part of our investments have been sold, and owing to the disorganised state of international trade the return for the Banking services greatly reduced. How then are we paying for that £790 millions worth of excess of imports? A large part of it still represents payment for the services of our ships, for though the tonnage is greatly reduced, the freights are much higher. But what about the enormous balance still unaccounted for? Our expenditure has exceeded our income, and for a nation, as for an individual, that is a serious matter. We have sold our securities abroad, and we are now mortgaging our capital assets to pay for imports which we cannot pay in exports. Worse still, we have raised enormous sums in the United States and in neutral countries on Treasury Bills and other short-dated securities. In the case of an individual we would call them I.O.U.'s, but in National affairs the other term sounds better, though they amount to the same thing. The money raised in this way has been used by the Government to pay for the goods it has bought in the United States and elsewhere, or it has been lent to the banks which have re-lent it to importers. In short, the excess of imports has been paid for by *borrowed* money. We have, of course, lent large sums to our Allies and to the Dominions ; but while many of their debts to us are likely to prove "bad debts" our debts to others must be made good. In any case, we have borrowed abroad much more than we have lent, and there is a considerable balance of foreign debt against us. We have changed from the position of a Creditor nation to that of a Debtor, and it is only now when the exchanges are set free to work on normal lines that we are beginning to feel the serious effects.

Up to March last the Exchanges were regulated by our Government so as to prevent them moving against us. During the war we made heavy purchases of war material and supplies from the United States and other countries, so that, on balance, we were their debtors. As a result, the foreign exchanges would move against us, and so, to prevent this the exchanges

were artifically supported. Several agencies were employed for this purpose.

1. Imports were restricted—partly it is true from shortage of tonnage—but also to reduce the amount owing by us to other countries.

2. Exports were encouraged in order to increase the amount owing to us. As this did not prove sufficient, the next step was

3. To raise loans abroad. At first sight it seems strange that when the exchange is going against us and because we are debtors, we try to remedy it by getting further into debt. But when we floated a loan, say in the United States, the U.S. became our debtor until the loan had been paid over, and in this way the balance was temporarily put in our favour.

4. Lastly the Government took over large amounts of foreign securities owned and held in this country, and employed them to create credits abroad, thus lessening the balance of indebtedness.

By these means the exchanges were prevented from moving too much against us during the war. But in March last this regulation came to an end, and we are now beginning to see where we stand. The position is a serious one. We are in the same case as an individual living beyond his income, and the remedy is the same—Spend less and earn more. We are a debtor nation and no juggling with figures can alter the fact. The situation is so grave that it calls for all-round sacrifice. It calls upon us for a rigid reduction of consumption, especially of luxuries, thus setting goods and labour free for the export trade. It calls on us to go on saving every penny, and thus to cheapen the supply of capital needed for industry; and it calls on everyone engaged industrially to increase production to the last ounce in his power and thus make a direct contribution to the liberation of the nation from its load of debt.

Professor Meredith, Queen's University; Mr. R. G. Geale, the City Accountant; and Mr. A. H. Muir spoke to the lecture, and the proceedings concluded with a vote of thanks to the lecturer.

Members of the Society wishing to propose new members should communicate with the Hon. Secretary at the Headquarters—The Museum, College Square North, Belfast.

This Society will celebrate its Centenary in 1921, and it is hoped that a record membership will be attained before that date.

BELFAST

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THE DYEING OF PURPLE IN ANCIENT ISRAEL.

BY REV. ISAAC HERZOG, M.A., D.LIT.

CATALYSIS OR THE SPEEDING-UP OF CHEMICAL REACTIONS.

BY A. KILLEN MACBETH, M.A., D.Sc., F.I.C., M.R.I.A.

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Professor Gregg Wilson, President of the Society, in the Chair.

THE DYEING OF PURPLE IN ANCIENT ISRAEL.

By Rev. Isaac Herzog, M.A., D.Lit., Chief Rabbi of Dublin.

(Abstract.)

Varied as are the meanings of the term purple in modern usage, to the student of antiquity the word denotes a cloth dyed with a colouring matter furnished by certain marine snails. And the tinting of cloth by means of marine animal pigment is still practised, albeit in a crude, primitive form, by the natives of certain coasts of Central America.

Our principal authorities as to the species of marine snail anciently employed in purple-dyeing are Aristotle and Pliny, but their statements leave much to be desired. Aristotle, in the fifth book of his History of Animals (chap. 15), states that it is the genus πορφύρα (*Purpura*) which furnishes the pigment for the dyeing of purple. In close association with the *Purpurae* Aristotle also gives some account of a genus called κήρυξ (*Keryx*) without, however, distinctly referring to its employment in the dyeing of purple. Pliny, on the other hand, speaks of two genera utilised for the manufacture of purple, namely, *Purpura* and *Buccinum*. It is assumed by all writers on the subject, at least as far as my research has extended, that the *Keryx* of Aristotle and the *Buccinum* of Pliny are identical; but in my work on *Tekelet*, still awaiting publication, I have shown that there is very serious ground for questioning the identification.

Modern research on this subject began with the identification by Guillaume Rondelet (d. 1556), Professor at Montpellier, of the *Purpura* of Pliny with the species now termed *Murex*

brandaris; and the chain of inquiries has been practically continuous down to the present day. To William Cole, an Englishman, belongs the credit of having for the first time after the total extinction of purple-dyeing, re-discovered (1681) the remarkable properties of susceptibility to light, and of colour-progression under its action, possessed by the fluids secreted by certain molluscs. W. R. Wilde, an Irishman, made a substantial contribution towards the solution of our problem by his discovery of huge deposits of shells of *Murex trunculus* on the shore of ancient Tyre, the home of purple-dyeing. Special mention must also be made of the striking researches of Lacaze-Duthiers. His "Mémoire sur la Pourpre" (1857), narrates his experiments on the secretions of *Murex trunculus*, *M. brandaris*, *M. erinaceus*, *Purpura hœmastoma* and *P. lapillus*, and sheds a flood of light on the statements contained in Aristotle and Pliny.

The net result of the study of the classical texts, combined with archæological discoveries and scientific experiments, has been the establishing, beyond a shadow of doubt, that at least the following species were anciently employed in the manufacture of purple:—*Murex brandaris*, *M. trunculus*, and *Purpura hœmastoma*.

Purple in the Bible and in Talmudic literature is mentioned under two designations, *tekelet* and *argaman*. While *argaman* is generally explained as red or violet-red purple, there is less consensus among translators with regard to *tekelet*, but the prevailing view is that, contrary to the traditional interpretation, it denotes not a dark pure blue, but rather a dark violet, inclining to blue. In my work on *Tekelet*, however, I have shown, I believe conclusively, that if not actually so in the strictly scientific sense, the tekelet-colour did not, at all events, *appreciablg* differ from a dark pure blue, the nuance assigned to it by tradition. It is generally assumed that both *tekelet* and argaman are varieties of purple, or in other words, of stuff dyed with sea-snail pigment. That *argaman* was of this nature is attested by the Septuagint, the oldest translation of the Bible.

Wherever *argaman* occurs in the Bible it is rendered by πορφύρα or one of its derivatives; and πορφύρα without a qualifying epithet means, of course, purple dyed with the pigment of sea-snails. *Tekelet* is rendered in the Septuagint by ὑάκινθος, a designation which does not necessarily imply that the dye is of molluscan origin. Philo and Josephus, moreover, while expressly mentioning the conchylian origin of the dyestuff used for *argaman*, are silent in regard to the source of the pigment producing *tekelet.* Talmudic tradition, however, fills the gap. A Talmudic text, going back in all probability to a time when the Second Temple was still in existence, dispels all doubt on the matter by declaring that *tekelet* used for ritual purposes must be of conchylian origin. The Talmud, moreover, contains a description of the species used for dyeing *tekelet*, and also an account of the actual process of dyeing tekelet for the "fringes" (Numbers xv).

The exact determination of the species used in ancient Israel for the dyeing of *tekelet* and *argaman*, and particularly the former, is a task fraught with almost insuperable difficulties. Various suggestions have been made, but it has fallen to the lot of Dr. Alexander Dedekind, keeper of the Museum of Egyptian Antiquities in Vienna, to press Lacaze-Duthiers' far-reaching results into the service of Semitic archæology. He maintains that Lacaze-Duthiers' researches have once for all furnished the clue to the identification of *tekelet* and *argaman* respectively. In the fourth book of his Beiträge zur Purpurkunde (p. 226) he gives the following classification:—

Purpura lapillus *Murex erinaceus* *Murex trunculus*	belong to the *tekelet* variety of purple, i.e., violet or blue purple.
Murex brandaris *Purpura hæmastoma*	belong to the *argaman* variety of purple, i.e., red or scarlet purple.

He regards *Murex trunculus* as the *tekelet* species, but also names *M. erinaceus* as a possible identification, though in view

of the minuteness of the dye-secretion in that species its employment for dyeing was unlikely. His omission of *Purpura lapillus* is probably due to the fact that this species is not found in the Mediterranean.

The identification adopted by Dedekind, be it carefully noted, is based solely on the tradition of the *tekelet* nuance: it does not take into account the description of the *tekelet* species as given in the Talmud, and as reproduced by Maimonides, the greatest authority of Post-Talmudic Judaism. And if we are to choose between the three species known to have been employed in Phœnician purple-dyeing (*M. trunculus*, *M. brandaris*, and ***P. hœmastoma***) there can be little hesitation so far as *tekelet* is concerned. *Murex trunculus* is the likeliest of the three; but there is the possibility that *tekelet* was produced from an altogether different species.

The description given in the Talmud of the tekelet species runs as follows :—

(*a*) Its body (i.e., the colour of its body or shell) is like unto the sea ; (*b*) its shape is like unto a fish ; and (c) it comes up once in seventy years, and with its blood tekelet is dyed, and therefore it is very dear." (Menahet, 44a). Another ancient text (Baraita a'Sisit) offers a variant reading : "What is Hilazon* like unto? Its shape is like unto that of a fish, and its body (i.e., the colour of body or shell) is like unto the sky, and it only comes up once in seven years ; therefore it is very dear."

Which species of marine snail satisfies the description thus recorded in the Talmud and the Baraita a'Ṣiṣit?

Before we attempt to answer the question it is essential to ascertain the import of the three elements constituting the description in the Talmud.

(*a*) This presents no difficulty. It refers to a deep blue or deep violet blue resembling the colour of the Mediterranean or of the clear cloudless Palestinian sky in bright sunshine.

*Hilazon in general means a shell-snail. In this instance it means the particular species furnishing the *tekelet* dye.

(*b*) The second element offers considerable difficulty. From the sporadic allusions to the nature and characteristics of fishes it is exceedingly difficult to evolve a clear idea of the type "dag" (fish) in the Talmudic conception, though one gains the impression that it does not materially differ from the modern conception of the term fish. Seeing, however, that on the one hand the *Gastropoda* and *Cephalopoda* are probably included in the term "dag" as used by Maimonides, and that the *tekelet* species is described by him as "dag," we are led to think that the characteristic (*b*) in the Talmud description does not exclude these classes of marine snails.

(*c*) The last point in the description also offers certain difficulties. Science knows nothing of a comet-like septuagenarian appearance of any of the denizens of the sea. In reality, however, "once in seventy years" is a hyperbolic expression. It amounts to saying that the species is caught at long intervals of time.

Murex trunculus fails to satisfy characteristics (*a*) and (*c*) of the Talmud. A serious difficulty in the way of the identification with *Murex trunculus* is also offered by the fact that the dye furnished by the latter is of a fugitive nature, while *tekelet*, as we know from the Talmud, was exceedingly fast. This difficulty can partly be met by the consideration that the *tekelet* dye used to be mixed with certain drugs, not specified in the Talmud. They may have served as stiptics for the purpose of endowing the colour with the quality of durability and fastness, but I do not think this very probable.

If for the present all hope is to be abandoned of rediscovering the *tekelet* species among the members of the genera *Murex* and *Purpura*, it might not be amiss to look for the same within the confines of the genus *Janthina*. The two species of this genus that live in the Mediterranean are *J. pallida*, Harvey, and *J. prolongata*, Blainville. These furnish a blue colouring fluid playing into violet. They live in the high seas, at the surface, and their colour is of a beautiful violet blue, which might easily

be confounded with the colour of the sea. Lastly they, like a great many pelagic animals, abound for some years to an enormous extent, whereas in the preceding period they had been rare or even extremely rare.

Mention may also be made of the fact that the dye-secretion of *Janthina* is fairly abundant in quantity : in *J. prolongata* the secretion, in fact, amounts to an ounce. This tends to corroborate the identification with the *tekelet* species ; for while in the classical authors the extreme expensiveness of purple is attributed to the minuteness of the purpurigenic matter in the animal, in the Talmud the preciousness of *tekelet* is ascribed solely to the rare appearance of the species.

Pending further research which, let us hope, will one day be undertaken along the Palestinian and Syrian coasts by specialists from the future Hebrew University of Jerusalem, the suggested identification with *Janthina pallida* and *J. prolongata* is, I venture to say, deserving of serious examination.

The Process of Dyeing.

No other material but wool was admissible for *tekelet*, *argaman*, and *tolat shani* (scarlet) of a sacerdotal and ritual character, and for the tekelet of the fringes.

In Greek and Latin authors πορφύρα, *Purpura* and their derivatives stand for woollen or silken stuff dyed with purple pigment. Silk purple was probably not unknown in Phœnicia and Palestine, but in the Temple its use was excluded by tradition. There can be but little doubt that purple dyeing in its early stages was confined to wool. Silk purple being a later extension of the industry, naturally failed to gain admission into the sanctuary or the ritual.

The wool was dyed in its raw state, the spinning, weaving, &c., forming subsequent processes. This is apparent from certain stray allusions in the Talmud, and is also corroborated by classical authority in regard to the manufacture of purple. (Compare also

Exodus XXXV, 23 with v. 25). No account of the mode of dyeing has been preserved by Jewish tradition in connection with *argaman*. *Tekelet*, however, has fared better, though the account given in the Talmud by R. Samuel bar Judah leaves much to be desired. "Abayi" records the Talmud, said to R. Samuel bar Judah,—"Now about this *tekelet*—how do you dye it?" He said to him, "We take the blood of the hilazon (i.e., the dye secretion of the *tekelet* species) and drugs (Sanmanim), put them into a kettle, boil the mixture, and then take out something of the liquid in an egg-shell, and test the sample with a bit of soft wool.* We then throw away that egg-shell and burn that sample of wool." No particulars are given of the "drugs" employed together with the dye-secretion of the *tekelet* species. Commentators differ. The Tosaphists, the French school of Talmudial exegesis, remark that "it is very strange that extraneous matter should have been mixed with the *tekelet* dye," "but perhaps," they add, "it was the combination of the *tekelet* pigment with these drugs that constituted the *tekelet* dye." Rashi, the foremost commentator of the Talmud, would seem to hold that the drugs in question were simply mordants used for fixing the colour in the fibre, and had nothing to do with the production of the colour itself. An earlier authority, Samuel ben Hofni, principal of the Academy at Sura, Babylonia (d. 1034) would seem to be of a contrary opinion. In a treatise extant as a unique manuscript at the library of Petrograd he asserts:—"the information has been handed down to us that *tekelet* was dyed with the blood of an aguine (marine) animal called hilazon mixed with another (substance)." This rather gives the impression that the *sanmanim* or drugs formed an essential part of the dye, assisting in the production of the requisite colour. Appearances in the Talmud, I feel, point in the opposite direction. The absence of all specification of the *drugs* in question, tends to indicate that the latter stuffs were not essential to the production of the colour.

*Cf. Pliny, IX, 38.

This is really the opinion of Maimonides, the greatest codifier of Jewish law and ritual. In reproducing the Talmudic account of the dyeing of *tekelet*, he states : "The wool is soaked in chalk and washed until it is clean, and then boiled with *ahla* and the like, as is the practice of the dyers, in order to prepare the wool for absorbing the colour. The blood of the hilazon is then put into the vat (kettle) together with drugs such as kimonia (cimolia),* as is usual in dyeing ; the liquid having been raised to a boiling heat, the wool is immersed therein, remaining in that condition until it has the colour of the sky, and this is the *tekelet* used for the fringes."

Tests for Detecting Fraudulent Imitations of Tekelet.

Imitations of purple with vegetable dye-stuff are referred to in Pliny, Vitruvius and other non-Jewish sources. I cannot, however, recall any reference to tests in Greek and Latin authors.

For *tekelet* the Talmud records two testing processes : one due to R. Isaac V. R. Jehudah, the other to R. Avira in whose name it was reported by R. Ada. In the first case a sample of the wool in question was allowed to soak overnight in a mixture of alumine, fenugrec juice and urine forty days old (or according to a variant reading urine of a forty days' old child). If the colour remained unimpaired, the *tekelet* was proved genuine. The other test consisted in putting some of the wool into an overfermented dough made of barley flour, and baking the dough. If after the baking operation was over, the sample on being taken out showed a change for the better in the quality of the colour, the wool would be pronounced genuine *tekelet* ; if for the worse, it would be rejected.

The *tekelet* imitations were usually made with indigo, which being fast to light and washing, could not be easily detected as a fraud.

In test (1) we miss an indication of the proportions in

*Cimolia is a cleaning substance, a reference to which is often made in Pliny (XX., 81, etc).

which the several constituents are to be mixed. What is the value of these tests from the chemical point of view?

Professor Green, Professor of Tinctorial Chemistry at the University of Leeds, in reply to this and other questions* states:—"It would seem clear from the quotation given that the tests prescribed have the object of ascertaining whether the dye is easily reduced" (hydrogenated). Indigo is more readily hydrogenated and removed from the fibre in the form of its leuco compound than is the brominated indigo (of which the purple probably chiefly consists). In both cases the action probably depends on the evolution of the hydrogen by the fermenting organic matter. 2°. It seems likely that *tekelet* was faster than indigo. 3°. Indigo like all vat dyes is very fast to soap. In pale and medium shades it is not very fast to light, in which respect it is surpassed by brominated indigos. 4°. Brominated indigos are all brighter in shade than indigo itself. 5°. All vat dyes are fixed on the fibre by oxydation. In the bath the dye is not present as such but as a soluble leuco or hydro compound. If the oxydation on the fibre is not complete, the dye will be easily removed by washing."

The Uses of Purple in Ancient Israel.

Allusions to the secular uses of *tekelet* and *argaman* are very few. Neither ever appears in connection with the royal apparel of Jewish Kings in Biblical times. In Canticles the seat of Solomon's palanquin is spoken of as being made of *argaman.* The virtuous woman is depicted as clothing herself in *shesh* and *argaman.* *Tekelet* is conspicuous by its absence.

The ritual uses of *tekelet* are two-fold, (I) for sacerdotal and cultual purposes, (II) for the sisit or fringes. (See Exodus XXV, etc., etc., and Numbers XV.) *Tekelet* appears as occupying a somewhat higher position than *argaman* in the ladder of sanctity.

The account of the First Temple in 1 Kings, 5-7, which of course is very far from complete, omits all mention of textiles.

* Dated July 29, 1913.

The parallel passages in Chronicles refer to *tekelet* and *argaman*, but in very general terms.

Ezekiel's sketch of the Future Temple contains no allusion to *tekelet* and *argaman*.

In the Second Temple *tekelet* and *argaman* were, we know, used not only for the High Priest's garments, in accordance with Pentateuchal prescriptions, but also for the thirteen veils hung at the gates.

The ritual use of *tekelet* for the sisit or the fringes survived the Temple by several centuries.

The law of sisit (the fringes) occurs twice in the Pentateuch Numbers XV, 37-41, and Deuteronomy XXII, 12.

The symbolic significance of *tekelet* is, I think, quite clear from the text of the Pentateuch itself. The *tekelet* resembling the sky-colour is to remind one of heaven, and so raise his feelings and thoughts to higher planes. This is, in fact, the traditional view of the significance of *tekelet*.

Though the rite of sisit is still observed, to some extent, by professedly orthodox Jews, and in a small measure even by reformers, *tekelet* has long ceased to form part of the sisit.

The Total Extinction of Tekelet.

Tradition singles out the territory of Zebulun, which, as we know, adjoined Phoenicia, as the centre of purple manufacture in Palestine.

This is significant in view of what we otherwise know of Phoenicia as a principal centre of the purple industry. A Talmudic tradition states in connection with Jeremiah, LII, 16 that Nebuzradan left some of the poorest people of the land to engage in the fishing of the purple-snails on the coast extending from the ladder of Tyre to Haifa. This would point to that stretch of territory as the home of Jewish purple-manufacture in ancient Palestine. The Hittite City Luz (Judges I, 26) is referred to in the Talmud as pre-eminent in the manufacture of *tekelet*. The reference may well be to a city in the vicinity of the Syrian

coast belonging to the great Hittite Empire in Northern Syria.

In view of the tradition crediting Phoenicia with the invention of purple-dyeing, and of the high esteem in which Tyrian purple was universally held in antiquity,* it is rather startling to find Ezekiel (XXVII, 7) referring to the Isles (or coast lands) of Elisha as furnishing Tyre with *tekelet* and *argaman*. This sounds like bringing coals to Newcastle. Where are those isles or coast lands of Elisha?

I am inclined to agree with Professor Sayce (Hasting's Dictionary of the Bible, S.V. Elisha) that Elisha adjoined the Mediterranean coast land. It may very well have been a Phoenician settlement, which would seem to have excelled about the time of Ezekiel, in the manufacture of purple. It would thus appear that the universally renowned Tyrian pre-eminence in purple production is subsequent to Ezekiel (died about 571 B.C.).

A classical source† names Sarepta, Caesarea, Neapolis and Lydda as cities supplying purple, thus indicating that the industry covered an area comprising the coasts of Syro-Phoenicia, Galileo, Samaria and Judaea. Migdal-Sabaja in the neighbourhood of Lydda (Lud) would seem to have contained an important purple market.

The question in how far the manufacture of *tekelet* in particular may have been affected by the imperial edicts issued from time to time concerning the fabrication of purple, its sale and use, is discussed at considerable length in my work on *tekelet*. For centuries after the destruction of the Second Temple extra-Palestinian Jewry was wont to procure *tekelet* for the "fringes" from the Jewish dye-houses in the Holy Land. There is a record of the importation of ritual tekelet into Babylonia about 506 C.E. It may safely be asserted that at the time of the completion of the Babylonian Talmud (C.E. 570) *tekelet* still continued in practice for the sisit or fringes. On the other hand in the Sheltot d' Rabbi-Ahai, a ritual work

* (Cf. for instance, Strabo, XVI, 11).

† Geog. Gr. Minores, II 5-13, 29.

composed in Palestine about 760 C.E., all mention of *tekelet* is omitted. The disappearance of *tekelet* from the Jewish ritual thus falls between the final redaction of the Talmud (C.E. 570) and the composition of the Sheltot (C.E. 760).

The Arab conquest of Palestine about the year 638 entailed the total destruction of the purple dye-houses administered by the imperial officials.† The final extinction of *tekelet* would also seem to have been one of the effects of the Arab conquest.

The great Jewish traveller, Benjamin of Tudela (C. 1160), makes mention of the dyeing of red-purple on the Tyrian Coast. It would thus appear that the industry revived some time after the Arab occupation. The interval must have been a fairly long one, seeing that the Jews who in Benjamin's time played an important part in the industrial life of Tyre* had made no attempt to resuscitate the dyeing of *tekelet* for ritual purposes; the chain of tradition must have been too long broken.

The art of purple-dyeing in general, which, dating from hoary antiquity—the mention of *tekelet* and *argaman* in the Cuneiform texts occurs already about 1600 B.C.—passed through a long and checkered career, finally becoming extinct, at least in the Old World, on the fall of Constantinople, May 29th, 1453.

It is worthy of note that the remarkable researches carried out by Gentile inquirers from William Cole to Lacaze-Duthiers found no echo in Jewish circles.

It was not until 1887, some 28 years after Lacaze-Duthiers' famous experiments that an attempt was made by a certain Rabbi, Gershon Enoch Leiner, of Radzin, Poland, to restore ritual *tekelet* in Israel.

He carried out investigations along the Adriatic coast, and eventually arrived at the conclusion that the *tekelet* species was identical with *Sepia officinalis*. In 1888 he established a factory for ritual *tekelet* in Radzin, dying a few years afterwards. The

†See Amati, De Restitution Purposes.

*See Benjamin of Tudela's Itinerary, ed. Asher, pp, 29-30.

dye-house founded by him was still in existence about the time of the outbreak of the Great War. The *tekelet* of Radzin has failed to obtain general acceptance, and its use is confined to a small circle of a few thousand families, consisting of admirers of the late Rabbi Leiner and of his son and successor.

That his identification of the *tekelet* species is entirely erroneous is conclusively shown in my work on *Tekelet.*

At the conclusion of the lecture the sincere thanks of the audience was conveyed to Dr. Herzog by the Chairman.

10th February, 1920.

Professor Gregg Wilson, President of the Society, in the Chair.

CATALYSIS OR THE SPEEDING-UP OF CHEMICAL REACTIONS.

By A. Killen Macbeth, M.A., D.Sc., F.I.C., M.R.I.A. Etc.

(Abstract.)

Part I.

The word catalysis is an unusual one and is doubtless unfamiliar to many, so at the outset a little space may profitably be devoted to an explanation of its meaning and application. It is derived from the Greek and means to *unloosen.* The term is now reserved for the description of those cases in which the progress of a chemical reaction is accelerated by the addition of a small amount of another substance, which is itself unchanged at the end of the reaction ; this may with some justification be regarded as an unloosening of chemical forces through the agency of the added material. The influencing agent is called a *catalyst.* A particular case will help to make the matter clear. A mixture of dry hydrogen and oxygen may be kept for a long time without any apparent union of the gases (to form water) taking place. The mixture may even be heated considerably without any appreciable combination resulting. If, however, a piece of clean platinum foil is added to the gaseous mixture the reaction immediately commences and sometimes proceeds with such vigour that the platinum becomes red hot and an explosion occurs. This is an example of the catalytic effect of platinum—a normally slow reaction being accelerated by its presence whilst the catalyst itself undergoes no change.

A good mechanical analogy is found in the case of a weight moving down an inclined plane. If the angle is gradually increased the plane is ultimately sufficiently tilted for the weight to start off and move slowly down the plane. Such motion may be regarded as representing a chemical reaction normally proceeding with small velocity. If the plane is now smeared with oil—the tilt remaining unaltered—it is found that the weight moves with a much greater velocity than in the preceding case. So we have the analogy to the increase in the rate of a chemical reaction by the addition of traces of a foreign substance. In the case of the weight moving down the plane it is evident that the oil cannot affect the actual force causing the weight to slide down the plane. It does, however, alter the resistance to the motion by decreasing the friction and so the velocity of the weight is increased,

$$\text{since Velocity} = \frac{\text{Force}}{\text{Resistance}}$$

In the same way a catalyst cannot be regarded as increasing the actual chemical affinities in a reaction but merely as acting in some way to decrease the resistance.

Many examples of catalytic action are known, but at this stage we may refer to two common cases. Potassium chlorate on being heated decomposes and gives off oxygen. If a little manganese dioxide is added to another quantity of the chlorate it is found that on heating, the oxygen is liberated much more rapidly and at a much lower temperature than in the first experiment. The manganese dioxide, moreover, may be recovered unchanged at the end of the reaction. Again, if a solution containing oxalic acid is heated with some nitric acid, little decomposition occurs. If a trace of a manganous salt is added the reaction proceeds briskly and the oxalic acid is broken down into carbonic acid gas. In these examples we see two criteria for catalysis, namely, (1) a catalyst can assist the course of a chemical reaction and itself remain unchanged and (2) a small

amount of the catalyst is sufficient to effect the reaction between large amounts of the reagents.

Before passing from the inclined plane analogy attention may be called to a further point. We can conceive the case of the plane being tilted to an angle much greater than that required to set the weight in motion. But if the weight is held by a clip it will not move until such an obstacle is removed. We find a parallel to this in what are known as "trigger" reactions: and just as no amount of oil will start the movement of the weight when it is held up by an obstacle, so trigger reactions are not recognised as catalytic phenomena. Examples of trigger reaction are found in the super-heating of water out of contact with dust and air and the crystallisation of supersaturated solutions. There is, therefore, an additional criterion for catalysis that is generally advocated, namely, that (3) a catalyst only affects reactions that are normally proceeding at a slow rate—in many cases at an immeasurably slow rate.

Substances which may act catalytically. In the early days of the subject it was thought that catalysis was the exception rather than the rule, but with increasing experiment the observations quickly reversed the belief and it would now appear that there are few reactions incapable of being materially assisted by the introduction of a suitable catalyst. The substances which act as catalysts range from the commonest to the rarest—from water to osmium, platinum, etc. Water, indeed, is a very general catalyst, bringing about the interaction of many gases that would not react if perfectly dry. For example, if sulphuretted hydrogen (dried by its passage over calcium chloride) is passed into a flask along with sulphur dioxide (dried by sulphuric acid) no reaction occurs : on adding a little water to the flask the gases immediately interact and sulphur is deposited. Again, carbon monoxide burns to carbonic acid gas, uniting with the oxygen of the air : but a jet of the dry gas will not burn in dry air. These are particular examples illustrating the catalytic action of water.

Of the metals, platinum and nickel are the most effective catalysts, and their efficiency is greatly increased as their fineness of division increases. Thus colloidal platinum and platinum black are incomparably more effective than platinum wire or platinum foil.

Theories of catalytic action.—Many views have been presented to account for the action of catalysts, and of these two deserve mention. The first—which may be regarded as the chemical view—supposes the catalyst to form transitional chemical compounds. Here the catalyst acts as a kind of middleman, inducing reaction between the two main reagents. The hypothesis may best be supported by reference to the reaction of sulphur dioxide with oxygen to form sulphur trioxide. This addition takes place but slowly in the absence of a catalyst. In the presence of a trace of nitrogen peroxide the difficulties disappear and the reaction proceeds quickly. This is explained by the nitrogen peroxide first parting with some of its oxygen to the sulphur dioxide to convert it into the trioxide. The resulting nitric oxide quickly takes up oxygen and is again converted into the peroxide, which is available for further reaction with sulphur dioxide. Thus a small amount of nitrogen peroxide is sufficient to bring about the union of large amounts of sulphur dioxide and oxygen. The transition of the catalyst into a lower oxide during the course of the reaction supports the view of catalytic action mentioned above.

There are many cases in which the intermediate compound view is untenable, notably in reactions which are accelerated by catalysts such as platinum or other finely divided metals. In such cases it is assumed that the catalytic power of the substance is connected with some physical property. The chief property that has been emphasised is that known as *adsorption*. Most substances have the power of condensing other compounds on their surface, and this is known as adsorption. Charcoal, for example, can take up about 170 volumes of ammonia gas ; it can also remove substances from solution, as is seen in the case of the

filtration of coloured solutions through layers of charcoal. This is purely a surface effect, and when it is recollected how large a surface is presented by the finely divided or colloidal metals, the probability of adsorption as a factor in catalysis is apparent. It has been calculated that if a sphere of gold with a radius of 1 m/m (about the size of a lead shot) were broken down into the colloidal state the particles would present a surface of nearly 1,000 sq. feet. On the adsorption view the reacting substances are condensed on the surface of the catalyst, and so are brought more closely together. There is therefore a greater chance of their reacting : and so the velocity of the reaction is increased.

These are the outstanding views that have been presented to account for the action of catalysts in speeding-up chemical reactions. Whether they are a correct representation of the state of affairs matters but little, as the application of catalysis to commercial operations is fortunately not dependent on such explanations. So without further enquiry we may proceed to examine some of the outstanding uses of catalysts in industrial processes.

Part II.

The Catalysis of Commercial Chemical Processes.

In introducing the second part of the subject, we may first look at a particular case illustrating the effective application of catalysis to a commercial problem. In the manufacture of carbonate of soda (washing soda) from common salt, two great difficulties were encountered in connection with bye-products formed during the process. In the first place large amounts of hydrochloric acid were produced during the course of manufacture, and as there was no great demand for this, it was allowed to escape into the air through tall chimneys. The acid which thus escaped was carried down by rains and had a very harmful effect on the vegetation of the surrounding country. This and other public inconveniences gave rise to widespread grievance, and the manufacturers were compelled to dispose of

the acid otherwise. They made use of the great solubility of the acid in water, and discharged it into neighbouring streams : but the streams so polluted were the cause of the destruction of fish, and in consequence this practice also had to be abandoned. After some study of the question it was found that if the hydrochloric acid fumes were mixed with air, and passed over heated bricks which had previously been moistened with a solution of cuprous chloride, a reaction took place, and chlorine was produced. The chlorine was absorbed by lime, yielding bleaching powder, for which there was a brisk demand. Thus by the catalytic action of cuprous chloride, a bye-product which had previously not only been a loss but also a nuisance to the manufacturers, was transformed into a valuable compound which proved a very welcome source of revenue to the companies.

The second bye-product in the process was a substance known as 'black ash,' consisting largely of calcium sulphide. For this there was no demand, and it was therefore tipped-up outside the works. In course of time mountains of this waste material had accumulated and proved a vexatious question to the manufacturers, not only on account of the space it occupied, but also because of the offensive smell. It was found that the calcium sulphide could be made to yield its sulphur in a very pure state, and as this was a good marketable substance the question of the profitable disposal of the black ash was settled. The calcium sulphide is decomposed by carbonic acid gas, yielding calcium carbonate (chalk) and sulphuretted hydrogen : the latter is converted by the catalytic action of iron oxide into sulphur and steam when a mixture of it and air is passed through a kiln packed with iron oxide. Thus the discovery of suitable catalysts gave a new lease of life to the Leblanc alkali process and enabled it to compete successfully with newer rivals.

Sulphuric Acid Manufacture.—In the further study of the bearing of catalysis on manufacturing questions the difficulty is not one of dearth of material, but is rather a question of making a judicious selection that may prove both interesting and instruc-

tive. A prior place may be given to the process of acid manufacture. It has been said that the wealth of a nation may be gauged by studying its consumption of sulphuric acid. This acid is extensively employed in manufacturing operations and so the quantity used gives an indication of the commercial activities of a nation. The acid results from a solution of sulphur trioxide in water. When sulphur (or an ore containing a high percentage of sulphur) is burnt in air, a gas known as sulphur dioxide is obtained. This unites with oxygen to form the trioxide. The manufacture of sulphuric acid therefore centres round the question of an effective process for combining sulphur dioxide with atmospheric oxygen. This is brought about by two processes, both of which involve the use of a catalyst. The Chamber Process depends on the catalytic power of nitrogen peroxide which has already been referred to. The Contact Process rests on the action of various agents, which promote the union of the gases when the mixture is passed over layers of the catalyst. Iron oxide is found to induce a sixty per cent. union of sulphur dioxide and oxygen if the temperature is about 600°C. Asbestos impregnated with a solution of platinic chloride (known as platinised asbestos) is a much more effective, but more expensive, agent. An interesting point may be noted in this connection. If the gaseous mixture contains certain impurities—notably arsenic—the efficiency of the catalyst rapidly decreases and in time its power disappears completely. This is referred to as *poisoning* of the catalyst and is a point which demands much attention in all catalytic processes.

The Nitrogen Question—The next operation which may be described deals with the manufacture of ammonia and nitric acid. It has been said that the fate of a nation probably rests on two simple compounds of nitrogen—ammonia and nitric acid. This seems a very remarkable statement and deserves examination. Taking a wide view of the matter we might say that the three chief factors in a nation's life are her commerce, her armaments and her food production. Without her commerce she must

decline; without her armaments her defensive and offensive powers vanish; and without sufficient foodstuffs her population cannot carry on the necessarily unequal contest. In all three of these we find ammonia and nitric acid, but especially the latter, play an important part. Nitric acid is extensively used in industries, such as the manufacture of dyestuffs and other chemical products. All explosives are derived from it or its salts. Food production is also intimately connected with it. In this connection we must briefly examine our needs. The animal body is largely composed of proteins which in the wear and tear of daily life are undergoing incessant wastage and so stand in need of continuous repair. The proteins are largely composed of combined nitrogen, so animal diet must include a fair amount of nitrogenous material. Animals are unable to make use of free nitrogen, such as might be obtained from the air we breathe; in addition animals are unable to assimilate simple compounds of nitrogen, such as nitrates or ammonium salts. The nitrogen diet must be composed of organic compounds already built up to the protein stage by plants or derived from other animals. It is thus evident that animals are ultimately dependent on the plant world for their supplies of nitrogen. Plants can take in nitrates from the soil and convert them into vegetable proteins, such as gluten of wheat. Now there are not great amounts of nitrates in the soil. Some compounds containing nitrogen are present in the humus of the soil; others are carried down by rains. Plants are, therefore, mainly dependent for their supplies of nitrogen on the humus of the soil, which results from the residues of preceding crops and the introduction of animal manures.

There is a profit and loss account on the farm, and so the land gets exhausted. There is a steady drain ou the farm, the crops produced being diverted to the centres of keenest demand; and so most of the foodstuffs raised, instead of being consumed on the farm, are sent to the cities. Stock raised is also sold off. So it is evident that there is a steady export of nitrogenous com-

pounds which necessarily exhausts the soil. To carry the story on, it need but be stated that the nitrogenous compounds sent into the city for consumption ultimately find their way in sewage to the sea, and so are lost.

The researches of Lawes and Gilbert and other agricultural chemists showed that the application of nitrate of soda or sulphate of ammonia greatly increased the yields of crops. The practice so introduced was greatly extended, and an enormous demand grew up for these artificial fertilisers. The chief source of sulphate of ammonia is the bye-product produced in the gas works throughout the country, and this is very limited. The chief source of nitrates was the nitre beds in Chili where sodium nitrate deposits were found. The amount of sulphate of ammonia is small, and it was found that the demand on the Chili beds was so great that calculations predicted that they would be exhausted in the year 1923. Considerations of this nature gave rise to what was known as the nitrogen question; and Sir William Crooks, speaking at the British Association at Bristol in 1898, for reasons such as we have hinted at above, said: "England and all civilised nations stand in deadly peril of not having enough to eat. As mouths multiply food resources dwindle." And further he added: "I hope to point a way out of this colossal dilemma. It is the chemist who must come to the rescue of the threatened communities. It is through the laboratory that starvation may ultimately be turned into plenty."

Efforts then were made to prepare nitrates and other compounds of nitrogen on a commercial scale. In the atmosphere there are practically unlimited amounts of nitrogen; but nitrogen is a very sluggish element, combining but slowly with most other elements. It can be made to unite with oxygen under the influence of electrical discharge, but this is not a catalytic process, and so does not concern us here. It can, moreover, be made to combine with hydrogen by the influence of certain metals, and this forms the basis of the Haber process for producing ammonia.

Nitrogen obtained from air is mixed with hydrogen and forced at a pressure of some 200 atmospheres (3,000lb. per sq. inch) over heated osmium or other catalyst. Ammonia is produced, which is condensed by means of a freezing mixture, and collects in a special receiver. The process is very efficient, and other cheaper catalysts may be substituted instead of osmium, which is very expensive. Iron, it would seem, acts as a very suitable catalyst.

A very old experiment—shown to illustrate the oxidation of ammonia to nitric acid—consists in bubbling oxygen through a moderately strong solution of ammonia and introducing a heated spiral of platinum wire into the vapour. The platinum continues to glow, and white fumes of ammonium nitrate are formed, due to the oxidation of some of the ammonia vapour. After many years Ostwald gave a modern application to this experiment, and built up the commercial process for preparing nitric acid by the oxidation of ammonia. Platinum acts as a catalyst in the process, and a mixture of air and ammonia is passed rapidly over a layer of half an inch of the catalyst heated to 300°C. The velocity of the mixture must be great, as otherwise the process is not effective. Stoneware vessels are used in the manufacture, as the hot nitric acid would attack any metal with great vigour.

By methods such as we have outlined atmospheric nitrogen is converted at a reasonable cost into ammonia and nitric acid: and the Nitrogen Question is thus solved.

Hardening of Oils. Another application of catalytic action which in recent times has become important deals with the hardening or hydrogenation of oils. Most vegetable oils are fluid or semi-fluid under ordinary conditions. Such oils are of much less value than hard fats, as they are not suitable for commercial processes such as the manufacture of margarine, candles or soap. On examining these vegetable oils it is found that they differ from the fats in having a lower hydrogen content. They are *unsaturated*, and are capable of taking up additional hydrogen atoms. The problem of converting an oil into a more valuable fat therefore centres round the most effective way of causing it

to add on further hydrogen atoms. Finely divided metals prove to be effective catalysts, and finely divided nickel is a most effective agent. The general method now practised is to pass steam over hot coke. Water gas—which is a mixture of hydrogen and carbon monoxide—is formed. The water gas is then passed over nickel heated to about 100°C., and the carbon monoxide reacts with the nickel, giving a volatile compound known as nickel carbonyl, which, together with the hydrogen, is passed into the hot oil. The nickel carbonyl is decomposed, giving off carbon monoxide again and depositing nickel in a very fine state of division. This finely divided nickel acts as the catalyst causing the hydrogen to combine with the oil. By this method an oil may be hardened to any desired degree. Oils so hardened are employed in the manufacture of soap and candles; they are also largely used in the manufacture of margarine. In this latter connection it is interesting to point out that traces of nickel remain in the hardened oils, and might have a harmful effect if the oils are used for human consumption. No limit to the permissible amount present has yet been fixed, but actual experiments have been conducted with a view to examining the effects of nickel compounds on health. As much as half a gram of nickel oxide has been given daily in a diet without ill-effects, 99·8 per cent. of the metal being rapidly excreted: and hardened oils contain very much less nickel than this, in fact, about one hundreth of this quantity per pound.

Synthetic Rubber. Since the introduction of the pneumatic tyre the demand for rubber has gone forward by leaps and bounds. The supply is derived from the sap exuded from the barks of certain trees in the rubber plantations of Ceylon, Java and elsewhere. It is not surprising that efforts were made to produce rubber synthetically—that is, to prepare it by purely manufacturing processes from simpler substances. Rubber, on being decomposed by heat gives, amongst other products, a liquid called isoprene. This liquid is also obtained from other sources, notably turpentine. Sir William Tilden made a comprehensive

study of isoprene and established its structure. In the course of a paper read at Birmingham in 1893 he said: "I was surprised a few weeks ago at finding the contents of the bottles containing isoprene from turpentine entirely changed in appearance. In place of a limpid, colourless liquid, the bottles contained a dense syrup in which were floating several large masses of solid of a yellowish colour. Upon examination this turned out to be india-rubber . . . . ."

This then represents the first artificial production of rubber. Efforts were made to accelerate the polymerisation of isoprene to rubber and many agents were found to promote the change. In 1910 Matthews discovered that sodium had a very pronounced catalytic effect and by varying the conditions the change could be completed in a few hours or a few days. The condensation of isoprene to form rubber can therefore be accomplished and the next step in the process to make it a commercial proposition is to ensure large supplies of isoprene at a low cost. Turpentine is out of the question, not only on account of its price, but also because only very limited amounts of it are available. A fermentation process was devised whereby starch, obtained from potatoes or grain, could be converted into fusel oil, consisting largely of butyl alcohol. This, by the action of hydrochloric acid and the subsequent action of chlorine, is converted into a dichloro-derivative, and when the latter is passed over heated lime it is broken down into *butadiene*—a substance which resembles isoprene in its main chemical properties. By the agency of sodium the *butadiene* is polymerised to form an artificial rubber. It was claimed that rubber could be produced by this method at a cost (pre-war) of about sixpence a pound. It is too early yet to give a pronounced opinion about the process, but it seems to have great possibilities. The scarcity of rubber in Germany during the war might perhaps be taken as an adverse criticism of the manufacture of artificial rubber, or of the value of the rubber so produced.

Part. III.

Natural Catalysts or Enzymes.

Having examined the behaviour of catalysts and reviewed some cases of the application of catalysis in manufacturing operations, association of ideas carries one on to ask the question, Are any substances found in nature which function, or can function, as catalysts? Many substances are found elaborated in the presence of living organisms which assist definite chemical reactions occurring in the animal body, and doubtless also effect the changes that take place during the plant growth. Grain is largely made up of starch, but there is also present a substance known as *diastase.* The diastase can be developed by moistening the grain and allowing it to sprout. If the grain is subsequently crushed and allowed to stand in contact with water the diastase assists the breakdown of the starch into sugars. This is known as *hydrolysis*, water being added on to the starch, thereby converting it into sugar. This conversion of starch into sugar does not ordinarily take place, but it may be brought about in the laboratory by boiling the starch for some time with dilute sulphuric acid : the acid acts as a catalyst, inducing the addition of water. We are, therefore, brought face to face in these changes with the great contrast between the violent action of an inorganic catalyst and the quiet, steady working of the natural ferment, diastase.

Another example of natural ferments—or *enzymes* as they are called—is seen in the case of almonds. Almonds, when freshly ground, do not possess their characteristic odour. This, however, develops in the course of time and is due to the chemical change brought about by the enzyme *emulsin* which is present. From the almonds a substance known as *amygdalin* can be extracted which, when moistened and treated with emulsin, breaks down into sugar (glucose), prussic acid and oil of bitter almonds (benzaldehyde) to which is due the characteristic smell.

Another good example of enzyme action is found in the case of the extraction of indigo from the indigo-plant. This plant contains a compound *indican* which is a combination of the active principle of indigo with glucose. On steeping the plant in tepid water for 12-15 hours an enzyme acts on the indican and the indigo principle passes into solution from which it subsequently settles out on oxidation by atmospheric oxygen.

In the case of the animal organism enzymes are found to be very abundant. These natural catalysts have each a specific action. One set assists a particular reaction, another induces a different chemical change, and others accomplish hydrolysis of different types. In the saliva, for instance, an enzyme *ptyalin* is found which acts on starch to break it down into sugars. In the stomach *pepsin* is present which acts in the acid solution of the gastric juice to break down proteins into simpler bodies. In the alkaline pancreatic juice another enzyme *trypsin* occurs, which also acts on proteins. Fat-splitting enzymes are also present. So the work of the digestion and assimilation of food goes on, being accomplished by the agency of these catalytic compounds.

Attention might again be drawn to the gentle way in which the enzymes bring about the chemical changes for which they are responsible. A fat can be split into two parts in the laboratory by hydrolysing it (causing it to add on water). This is only brought about by boiling for a considerable time with dilute sulphuric acid or strong caustic soda solution. (The latter reaction is the basis of the change that takes place in soap manufacture). On the other hand a fat may be broken down into glycerine and the fatty acid by the action of the enzyme, *lipase*. This change goes on without appreciable rise of temperature, whereas with the inorganic catalyst considerable boiling is necessary.

The action of an enzyme has been compared to the unlocking of a door by a key : in contradistinction the action of an inorganic catalyst has been likened to the breaking down of the door by shatterings and smashings. In this we get the contrast between

the harmonious working of natural catalysts and the discordant work of artificial agencies.

The lecture was illustrated by experiments and lantern slides, and at the close on the motion of the Chairman a hearty vote of thanks was passed to the Lecturer, and to Mr. J. K. Marsh, B.Sc., who assisted with the experiments and the lantern.

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THE GREAT CHEMIST, JOSEPH BLACK: HIS BELFAST FRIENDS AND FAMILY CONNECTIONS.

BY HENRY RIDDELL, M.E., M.I.Mech.E.

THE USE OF COLLOIDS IN DISEASE.

BY ALFRED B. SEARLE.

A NATURALIST'S WANDERINGS IN NYASALAND.

BY PROFESSOR ROBERT NEWSTEAD, F.R.S.

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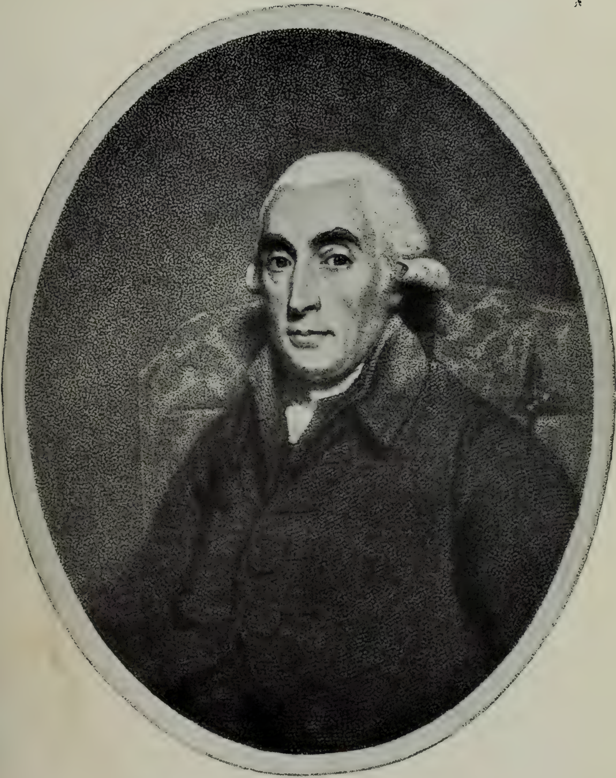


DR. JOSEPH BLACK.

From an Engraving in the Belfast Municipal Museum, published in 1803.

13th January, 1920.

Professor Gregg Wilson, President of the Society, in the Chair.

"THE GREAT CHEMIST, JOSEPH BLACK, HIS BELFAST FRIENDS AND FAMILY CONNECTIONS."

By Henry Riddell, M.E., M.I.Mech.E., Hon. Treasurer of the Society.

(*Abstract.*)

I make no apology for devoting the time available to-night to giving some account of the life and work, as well as of the family and friends, of one of the many remarkable men whom Belfast has given to the world for the development of scientific thought, a man held worthy to be mentioned along with Newton, and a fit member of that long list of great Irishmen, holding such names as Boyle and Kelvin and Stokes. Sir James Dewar has said that "the great Joseph Black was the first founder of modern chemistry; he was the first man to apply the balance; he was the first man to reveal and explain those interactions of heat and cold which were a mystery until his time."

It is true he was born at Bordeaux, where his father had gone into trade as a factor and wine merchant, much respected by the community and on terms of intimate friendship with the great Montesquieu. But his Ulster connection is incontestable, and will be dealt with later.

I am going to adopt an eccentric arrangement of my subject to-night, and bring first before you the great work done by Black as a chemist and physicist, partly by way of justifying my interest in himself, his family and friends. I shall try to interest you also in these friends and relations as I see them, and to speak something of the old town of Belfast as it existed one to two hundred

years ago, till the end of the first quarter of the 19th century. I shall finish up by a short biography of Joseph Black as a man, and I hope to leave you feeling as I do, that he passed through life as a gentleman, thoughtful for his students, his patients and his friends ; a loving son and brother and a faithful comrade.

To understand Black's services to science it is necessary to call to mind the condition of learning in physics and chemistry at the time his work was done, say, from 1750 to 1770. In those days Natural Philosophy was a term which covered all such branches of science as Physics, Chemistry, and those almost quite undeveloped studies, Geology, Biology and Zoology, and it is therefore not at all surprising to find that, as professor of chemistry, Black lectured upon the earth and the theories developed by his great crony, Hutton, and that his experiments in heat were also a chief part of his work. I, of course, remember that my great teacher, Dr. Thomas Andrews, really was a physicist teaching chemistry, rather than a chemist experimenting in physics.

In Black's earlier days there was little understanding of the relation between elementary bodies. The birth of Dalton, the originator of the conception of atomic weights, took place twelve years after Black had presented the famous Thesis written for his degree. It was in 1754 that Black wrote this thesis, while it was in 1766 that Cavendish discovered hydrogen ; in 1772 Rutherford separated nitrogen, and in 1774 oxygen was discovered by Priestly, the discovery which is really the foundation stone of modern chemistry. There were some observations earlier than Black's that might have given the clue, but they were not followed up, and till his time the fact that a gaseous element might exist in a solid form in a stone was totally unsuspected. Chemistry was then chiefly taught as a medical subject, and inseparably connected with the study of medicine, so that it is not strange to find the professorship of Anatomy and Chemistry held by the same man. Black was instituted professor of Anatomy and lecturer in Chemistry in Glasgow in 1756, and began there that long period of teaching chemistry which exercised such

an influence upon the world of science. Anatomy and Chemistry were not similar studies, and it is not surprising that Black soon managed an exchange of the chair of Anatomy for that of Medicine. In his medical lectures he distinguished himself by the perspicuity and simplicity of his work, and by the cautious moderation of all his general doctrines. We are really little concerned about his medical professorship, and only note it in passing as typical of the man as a teacher. Black's fame as a chemist depends on the work done while a student and while lecturing in Glasgow. After his removal to the chair of Chemistry in Edinburgh, his original research almost ceased. Teaching became his life work, and his exceedingly conscientious nature combined with feeble health prevented him from doing more than was necessary to keep his lectures abreast of the growth of chemical knowledge, and prepare the necessary experiments with which he illustrated his teaching.

His work was known and its value recognized everywhere. Later in the century, in 1791, when Black had finally accepted Lavoisier's ideas and the French system of nomenclature, and was so teaching his pupils, Lavoisier wrote him expressing his appreciation in a letter which I translate :—"I learn with joy more than I can express that you are so good as to grant merit to the thoughts and ideas which I have been the first to put forward against the doctrine of Phlogiston. Paying more attention to your ideas than to my own, accustomed to look upon you as my master, I mistrusted myself in that I had departed so far, without your approval, from the road which you had so gloriously followed. Your approbation disperses my scruples and gives me new courage. I shall not be content until circumstances allow me to bring to you myself the proof of my admiration, and to show myself among the number of your pupils."

So a reputation made by his great advances in science was maintained by the remarkable success of his teaching as a professor, to whose classes came pupils from many nations to spread his fame in France, Germany, Sweden and even in Russia.

I cannot forget the great admiration which our own Andrews had for Black's work, nor do I forget that it was in Andrews' address to the Chemical Section of the British Association in 1871 that Lavoisier's three letters to Black were first printed. Andrews himself had followed up Black's work by a remarkable series of investigations upon the latent heat of vapours, followed later by his world-famous enquiry into the relation between the liquid and gaseous states of matter. It is scarcely too much to say that these great advances in science were suggested by and partially at least due to the original labours of Dr. Black. Anyone who will read Black's lectures as edited by Robison and published in 1803, will agree that they are models of what such lectures should be. It is really hard to say whether science has lost or gained by Black's devotion to his teaching duties. It is certain that, relieved from this constant strain, he would have gone on from discovery to discovery, and perhaps some of those great results afterwards obtained by other chemists would have been the fruit of his genius. The great clearness of teaching, combined with the care to state nothing as proved which seemed in any way hypothetical; the fact that all knowledge lying within the scope of his lectures was carefully studied, digested and taught in the plainest and simplest language, had such an effect in inspiring his pupils that it is possible that the seeds thus sown brought a greater crop than could ever have come from the brain and exertion of one man devoted to research. Surely a great teacher is as great an asset to the world as a great investigator, and in Black's case the two could not be combined. I shall speak a little further about this when I deal with his life as a man, and will leave the personal now to say something about the actual researches which first brought him fame, and the circumstances under which they were made.

Black left school in Belfast in 1746 and entered Glasgow University at the age of 18. It was not an early age as matters went then. Those were the days of precocious youth, though not so generally precocious as was William Thompson many years

later when he entered the University at the age of ten. Perhaps you remember Kelvin's views as to the education a boy should have—"Every boy should be able by the age of twelve to write his own language with accuracy and some elegance, he should have a reading knowledge of French and be able to translate Latin and easy Greek authors, and have some acquaintance with German. Having thus learned the meaning of words a boy should study Logic so as to apply his words sensibly.'

Black was certainly not so precocious as this would require when he entered at the age of eighteen.

It was after the completion of his Arts course that he was required by his father to choose a profession, and selected that of medicine, as being more in consonance with his favourite studies, and at once began his work by attending the lectures of the Professor of Anatomy and of Dr. Cullen, then Professor of Medicine at Glasgow.

Dr. Cullen was really the first teacher of Chemistry in Glasgow University, and during Black's residence there began the lectures which were to have such an influence later. Black was selected as his assistant, and immediately began those researches which reached fruition in the thesis offered for his degree. Surely never was degree earned by such an epoch-making thesis. In its English form, as read a year or so later before the Philosophical Society of Edinburgh, its title, "Experiments upon Magnesia Alba, Quicklime, and some other Alcaline Substances," does not seem to have much connection with medical research. In reality, however, it was originally a true investigation for medical purposes, and this appears in the Latin title of the degree thesis, "De Humero Acido a cibis orto et de Magnesia Alba." Since I began my study of Black and his friends, his "Life and Letters" has been published, written by Sir William Ramsay, and the true begetting of Black's researches has been there explained at some length.

Sir Robert Walpole, and his brother Horace, afterwards Lord Walpole, were troubled with the stone. They imagined they

had received benefit from a medicine invented by a Mrs. Joanna Stephens, and through their influence she received five thousand pounds for revealing the secret, which was published in the *London Gazette* of 1739. Any of you anxious to know this medicine in all its details can study it in Ramsay's book; sufficient to say that it was mostly compounded from such things as egg shells, snails, calcined soap, honey, wild carrot seeds, &c., &c., all burnt to a blackness. Doctor Cullen and his colleagues held opposing views as to the efficacy of such remedies. It must be remembered that the medical treatment of calculus at this time depended upon the use of caustic alkalies, and Black began his experiments on magnesia with the object of obtaining a "milder" alkali, which would yet be more efficacious than those then in use. Chalk itself had no caustic properties, but when burnt its nature was completely changed. This was a common-place of the knowledge of the day, but the reason of the change was completely misunderstood. It was the day of the material theory of heat complicated by the extraordinary doctrine of Phlogiston due to Stahl, a doctrine which gave to Phlogiston a set of very puzzling properties.

Caustic Lime, obtained by burning the so-called calcareous earth, was looked upon as having received its causticity from something added by the fire used to obtain it. Then again, such Caustic Lime, mixed with the fixed or mild alkalies, became itself again mild calcareous earth, while the fixed alkali became caustic in its turn. What more natural explanation than the lime parting with the igneous matter it had received from the fire, and the alkali taking it up? It was known also that the Caustic Lime when exposed to the air gradually lost its causticity, becoming again a substance indistinguishable from the calcareous earth from which it had been obtained. What more certain, then, than that the igneous matter, the cause of the causticity, had escaped into the air, and the lime thus become reduced to its original state? And yet it had been long known that loss of weight had taken place in the actual calcination, and a curious

hypothesis was framed to account for this. The idea of an imponderable in Chemistry was common enough, but for the then purpose the facts required that the weight of the Phlogiston, or whatever name the caustic principle might be called, should be negative, surely something so contrary to the usual experience of matter that it might have given rise to more than doubt in the minds of the observers.

At first Black held the common view. He seems to have thought of the possibility of catching this caustic substance as it escaped into the air while the caustic lime gradually became transformed to calcareous earth. In his note books a couple of years before his degree thesis, experiments are mentioned with this object. He placed some caustic lime in a saucer floating in water and inverted a glass vessel over it. He notes the fact that nothing escapes, not only does the water not fall in level by increase of occupied space in the cover glass, but it actually rises slightly. Thus early is he upon the track of the solution. I need not follow his experiments in detail, but he succeeded in proving conclusively that causticity was due to the loss of a constituent in the gaseous form, which he named "fixed air." He showed the transfer of this fixed air from one alkali to another. He weighed and measured approximately the mass and volume of the fixed air, and showed that it maintained an unalterable relation to the mass of the particular alkali employed. He inferred its possible identity with the fixed air obtained by combustion of vegetable matter, and with a constituent of the air expired from the lungs of living beings. In fact he really and truly discovered carbonic acid, even to the extent of teaching that its compounds with the alkalies were exactly analogous to those formed by the mineral acids. This was the first time it had dawned upon chemists that a substance which when alone existed only in the gaseous form, might in combination be a solid and appear as a stone. The advance in chemical knowledge was inconceivable, and it is no wonder that he is looked upon as the father of Pneumatic Chemistry, or that the great Lavoisier should

have written with the copy of his book on respiration which he sent to Dr. Black—"It is but just that you should be one of the first to receive information of the progress made in a career which you yourself had opened and in which we consider ourselves your disciples." A very human touch is added by the fact that Black sent some copies of his thesis to his father who forwarded one to Montesquieu. After a few days the great president called on him and said—"Mr. Black, your son will be the honour of your name and family."

Robison, who edited Black's lectures in 1803, writes:—"What could be more singular than to find so subtle a substance as air existing in a hard stone, and its presence accompanied by such a change in the properties of that stone? What bounds could be reasonably set to the imagination in supposing that other aerial fluids, as remarkable in their properties, might exist in a solid form in many other bodies which at present attract no notice, because of our ignorance of their nature and their composition?"

The other great discoveries to which I direct your attention are those known as "latent heat" and specific heat. In modern teaching "latent heat" is known rather as the heat upon which the state of a body depends. Perhaps the most important example is found in water, which exists in the three distinct forms of solid, liquid and gas. Before Black's time it was believed, of course, that upon the temperature of the body depended its state, that as soon as ice reached the temperature of 32°F. it melted. It was assumed that the smallest addition of heat to the ice at 32° was sufficient, by raising its temperature slightly above 32°, to cause the ice to melt. It was also implicitly assumed that whatever quantity of heat was required to raise the water through one degree, the same quantity, added to ice at 32°, resulted in water at 33°. Similarly it was believed that the smallest addition of heat to water at 212° resulted in its conversion into steam. To Black the mere fact that ice took a long time to melt, and that the kettle on the fire was long in boiling

away all the water, seemed to indicate something very different from the common view.

It had also been assumed that equal quantities of heat were required to raise equal masses of every substance through the same range of temperature, and when it became clear from certain experiments that this was a mistake, it was suggested that "volume" should be substituted for "mass." Dr. Black showed that every substance had its own capacity for heat, dependent on its material, and laid the foundation of the doctrine of Specific Heat, which afterwards developed into the so-called law of Dulong and Petit, that the atoms of all elements in a gaseous state had the same heat capacity. He also showed that there were numerous cases in which large quantities of heat were added to bodies without any change in the temperature, such as that already mentioned in melting ice and in evaporating water. Thus for the first time the scientific world was provided with the idea now known as "heat consumed in, or arising out of, change of state." For perhaps all his life Dr. Black held the opinion that heat was some kind of substance, though he recognized the difficulties, and that the liquid state of water, as of other fluids, was due to the actual combination of this substance of heat with the material which became liquid, and in the combination ceasing to be recognizable by the thermometer, just as the gas or fixed air could not be recognized as forming part of the calcareous earth by any of its visible properties. It is really curious that when, as a schoolboy, nearly sixty years ago I began to study natural philosophy, the doctrine of latent heat was still taught in terms of combination of caloric, although the substantial character of heat was then rejected by almost every authority.

Black's first experiment was made by hanging in a large room, very little subject to change of temperature, two globes of thin glass, one containing water and the other ice. He assumed that heat was being constantly supplied by the air of the room to both globes. When the ice was almost all melted the temperature of the water and ice contained in the globe was still 32°, while

that of the water in the other globe had risen considerably. Further experiments were made by the method of mixing a known quantity of warmed water with a weighed mass of ice, and observing the resultant temperature, making due allowances for losses by radiation during the time occupied in mixing. Considering the difficulty of an unknown operation and the roughness of the apparatus available his results are extraordinarily accurate. Read in modern terms the latent heat of melting ice, as measured by him, is equal to 143 B.T.U. or a quantity of heat equal to raising the same mass of water, at say 40° to 183°, or through 143° approximately. The agreement is as exact, possibly, as the modern measure of 142·65 B.T.U. In estimating the same quantity for transformation of water into steam Black was assisted by James Watt, whose best results are given as between 900° and 950°. At 950° he was nearer than Lavoisier with intricate apparatus, who estimated the figure at 1,000° against the now accepted value of approximately 966°. I need not follow the matter further, but quote Robison—"Fahrenheit, Boerhave, Mavian, De Luc, and all the inquisitive meteorologist of the two preceding centuries, though incessantly contemplating and employing the same facts in their disquisitions, never mention having such a thought." "It is the undivided property of my ingenious and acute preceptor."

This perception of the latent heat of water and of steam was one of great importance in science and pregnant with great possibilities.

An ingenious explanation, no doubt partially true, was offered by Dr. Irvine who had been a pupil of Black's, and was seeking some method of finding absolute zero of temperature, now assumed as about 492° F. below freezing point. Irvine assumed that the total heat in any substance was proportional to the specific heat. That of ice is not much more than half that of water, so that the total heat of the ice was only about half that of the water, and the heat disappearing into the water when the ice melted was that required to bring up the total heat of the water to that

calculated by its specific heat. Of course this reasoning required the whole law of specific heat from ultimate zero to present conditions to be constant, or in an altered form, that this law should at least be known in all its steps. The results to science were not more remarkable than those to be found in another sphere. The steam engine, used chiefly in draining mines, was at that time a very uneconomical tool. For example it is stated that—"an engine having a cylinder of three feet diameter working continually consumes almost 3,000 tons of coal in a year." Fortunately for the world Dr. Black had a friend and pupil or assistant at the time in the person of James Watt, himself an experimentor of supreme merit and an acute reasoner. It is hardly too much to say that to these experiments of Black's, studied, and repeated and varied as they were by Watt, is due much of the great advance made by the latter in the construction of the Steam Engine, more particularly the Separate Condenser. Watt was then employed in fitting up the instruments in the McFarlane observatory, and got into his hands a small model of Newcomen's steam engine, and we all know the result of the combination of Black's suggestions with Watt's skill and imagination. Curiously enough, but also naturally enough, Black's discoveries reinforced for a time the material theory of heat, so that in 1803 we find Robison lecturing as follows:—"Here we observe another combination of heat or fire, the mighty agent by whose operation all these changes are affected. Heat, or the cause of heat, seems now to put on a real form, and as no longer to be considered as a mere condition or state, into which other matter can be brought, as noise or sound is known to indicate merely a certain undulating or tremulous motion of the air. But we now see heat susceptible of fixation, of being accumulated in bodies, and, as it were laid bye till we have occasion for it, and we are as certain of getting the stored-up heat out of the steam or water, by changing them into water or ice, as we are certain of getting out of the drawer the thing we laid up in it." This remained the common doctrine until 1840, and the singular

discovery with regard to radiant heat, that its rays were reflected and refracted in the same manner as those of light, was held to be a strong argument in its favour. It must be remembered that the emission theory of light was still in force, and that Newton's explanation of refraction was absolutely consistent with the then known facts, the constant relation between the sines of the incident and emergent ray. You remember Newton's calculation as to the force with which one grain of glass attracts the light which it refracts, that it is not less than the force with which a wire would be stretched by a hundred millions of millions of pounds of matter hanging by it. In one of his notes to Black's lectures Robison says—"This observation of the constant ratio of the sines of incidence and refraction, is the strongest argument that has yet been obtained for the materiality of heat. For this law of motion is competent only to a material particle, having mobility and inertia, and acted on by transverse accelerating forces, in the same manner that a cannon ball is acted on by gravity and by the force of projection." It is now universally accepted that heat is a form of energy, but what energy is independent of matter is a difficult conception. Radiant heat comes from the sun exactly as light, and it would seem clear that a vibration which our theories tell us exists in the ether of space, must be transmitted to and taken up by material bodies. The possible relations between the ether and matter are still to explain.

As has already been said there are no other great original investigations of Black's to be mentioned, but much good, if rather routine work was done. The most outstanding example was the analysis of water from a hot mineral spring, in which the methods employed were very novel and greatly in advance of the practice of the time. He was often invited to advise on problems of industrial Chemistry, and offered many acute suggestions.

It has been quite impossible to go into Black's work in detail, and it is fully time to say something of his family and friends.

Black's Family and Friends.

It is quite impossible to give in complete detail the histories of the many families in Belfast with which Joseph Black was connected; they include those of Eccles, Black, Wilson, Legge, Clarke and others; I must therefore confine myself to the closer relatives and most interesting personalities, and to the more curious results of the constant interlacing of the families of old Belfast.

John Black, of Belfast, the Grandfather of Joseph, was sworn in a Burgess of the town before Hugh Eccles, who was sovereign in 1675, and was, I have reason to believe, an uncle of John Black's wife.

John tells his own story in a letter to the head of the Lamont Clan, with which he claimed and was admitted to relationship.

The letter is written from Belfast in 1723 and from it I extract the following—"I have been an inhabitant of this place for about 60 years, except some intervals when I went abroad to France, Holland and the West Indies, &c., all which time I have been engaged in Merchandysinge . . . I was comfortably marryed to one of the name of Eccles, by whom I have five sons and two daughters yet alive, all the former brought up in France and Merchandysing, one of them settled a factor and marryed in Bordeaux and hath a family of six children, another is honoured to be King Georgs Consul at Cadiz, in Spain, where he enjoys both great honour and riches."—So that even two hundred years ago the natives of Belfast had developed that wandering instinct which has never left them. The factor at Bordeaux was his eldest son John, born 1681, and from a power of attorney issued by him in 1761 to his sons, we have a few words more as to his father and himself. "I, John Black, native of this town of Belfast, born in or about the year 1681 or 1682, son to John Black and Jane Eccles, his beloved and virtuous spouse, educated here, was in or about the year 1696 or 1697 accompanied by his

father taken up to Dublin and there bound apprentice to learn trade to his uncle Alderman John Eccles, afterwards Sir John Eccles who, with his father Mr. John Black, of Belfast, sent John Black, Junr., to go and reside at Bordeaux, in France, where he arrived in the year 1699, and remained some years as compting house servant, and clerk with Mr. George Boyd, of Coleraine, a distant relation of the family settled there a factor, who discontinuing the business young John Black from low circumstances and small beginnings acquired friends, acquaintances and a little good reputation and credit so as to commence there a factor for captains of ships, super cargoes and merchants in Great Brittain and Ireland who, giving him a good character for his sobriety, care and honest application and industry in business recommended correspondency with him to others and getting acquainted with worthy Robert Gordon, there a factor from Aberdeen and his spouse and family, did become enamoured of the person accomplishment and virtues of Mistress Margaret Gordon and desiring her in marriage their nuptial benediction was given in the year 1716, from whence is descended a numerous issue of eight sons and four daughters yet alive in 1761," The Jane Eccles mentioned was the daughter of John Eccles, of Cranmore, and sister of Sir John Eccles, afterwards Lord Mayor of Dublin. Cranmore was the house where John Eccles entertained William III on his way from Carrick to Drogheda. Eccles blood has flowed in so many channels that any resident of Belfast tracing his descent from one of the merchant families of the 17th and 18th centuries in our city, may with great confidence assume that he has a share. John Eccles had three daughters, of whom Jane married John Black, Mary became the wife of William Legge, of Malone, and the third married John Clarke, the ancestor of the Clarke family. In his journal in Bordeaux, dated December, 1754, John Black gives us more personal and family reminiscences. Joseph Black was at this time twenty six and the occasion is the birth of an heir to John Black's eldest son, also John, who had married in 1750 Jane Banks, a member of one of the leading

families in Belfast. Stewart Banks was five times sovereign between 1755 and 1788, and in the diary John Black registers his satisfaction—"On my coming over the river from Blamont to the Charterhouse, on Wednesday, the 14th December, 1754, to assist in our family devotions on Sunday, I was agreeably surprised with the welcome news of my daughter-in-law's Jane Black, safe delivery of a brave lusty boy christened the same day at St. Andrew's Church by the name of Jo John Black, the fifth so called in a direct line in a lineal descent of eldest sons in our family, originally of Scotland, of those invited over thence by James the First to colonize Ulster in Ireland, which had been laid waste and depopulated by the wars amongst the chiefs and their clans. My grandfather, John Black, born about Ballymenagh, in the County of Antrim, had been a trooper against Cromwell; my father, educated a merchant by Mr. Pottinger, of Belfast, had been often super cargo in the West Indies, at Cadiz, here at Bordeaux, at Danzick, Holland, England, Rouen, &c. myself at school in Air, returned to Belfast, 1690, at Latin and Greek until 1697."

The mention of the Pottinger family recalls a memory which Belfast ought not to let die. There is now no member of the family resident in Belfast, where once the name was so powerful. We find it now only in Mount Pottinger and in Pottinger's Entry, and yet members of the family made their mark in the commercial history of Belfast, and in the political history of the Empire. In China and in India their work brought changes even in world politics, but it would be outside my subject to do more than mention the name, and remind you that the life of Eldred Pottinger especially is a study full of intense interest. It is curious how many of Ulster blood have left their mark upon India—the Lawrences, Richardson, Pottinger, Gillespie, Dufferin and many others.

John Black was greatly respected in Bordeaux, and was on terms of the most intimate friendship with the great Montesquieu, who wrote him when his intention of returning to Ireland became

known :—"I cannot be reconciled to the thought of your leaving Bordeaux. I lose the most agreeable pleasure I had, that of seeing you and forgetting myself with you." The son John, who married Jane Banks, had issue by her, among other children a daughter, Eliza, born in 1751, whose second husband was Walter Bagenal, of Bagenalstown. A daughter, Maria, of this marriage became the wife of Lord Downs, and from them sprang two girls, Ann and Charlotte, who married respectively Lord Clonmel and Lord Seaton. There are four other children of John of Bordeaux, in addition to Joseph, which I should certainly mention. Isobel, who married James Burnett, of Aberdeen, and whose daughter became the wife of Adam Ferguson, the famous Moral Philosopher and intimate friend of Joseph Black. Ferguson was already related, being a cousin of Joseph's, his mother being one of the Gordons of Aberdeen. Then there was Katherine, born 1736, who married Francis Turnley of Newtownards. Her daughter, also Katherine, was wife of Ezekiel Boyd, and from this marriage sprang still another Katherine, who married the Rev. R. Gage, of Rathlin, and their daughter Dorothea, in 1864, became the wife of Prince Waldeck and Pyrmont. Black's two sons, Samuel and George, came to Belfast, where they became leading men among the merchants, holding the office of Sovereign between them no less than seven times from 1772 to 1789. John of Bordeaux died in Belfast in 1767 while on a visit to his son, and was buried in the family tomb in the old Corporation Church ground.

Samuel died in Belfast in 1792. George married in Belfast in 1753 Arminella, neice of Hill Willson of Purdysburn, and widow of a Mr. Campbell. He purchased Stranmillis and on it built a cottage for a summer residence, which was afterwards rebuilt by his son George in 1802. This son George was born in 1763, and in 1801 married Ellinor Stewart, a daughter of Robert Stewart of Ballydrain, a family with which the Blacks were already related by common ancestry. Before George could get married, however, he needed a settled position not dependent on his father, and he became Landwaiter, or Officer of Customs, in

"MARYVILLE" MALONE, BELFAST,

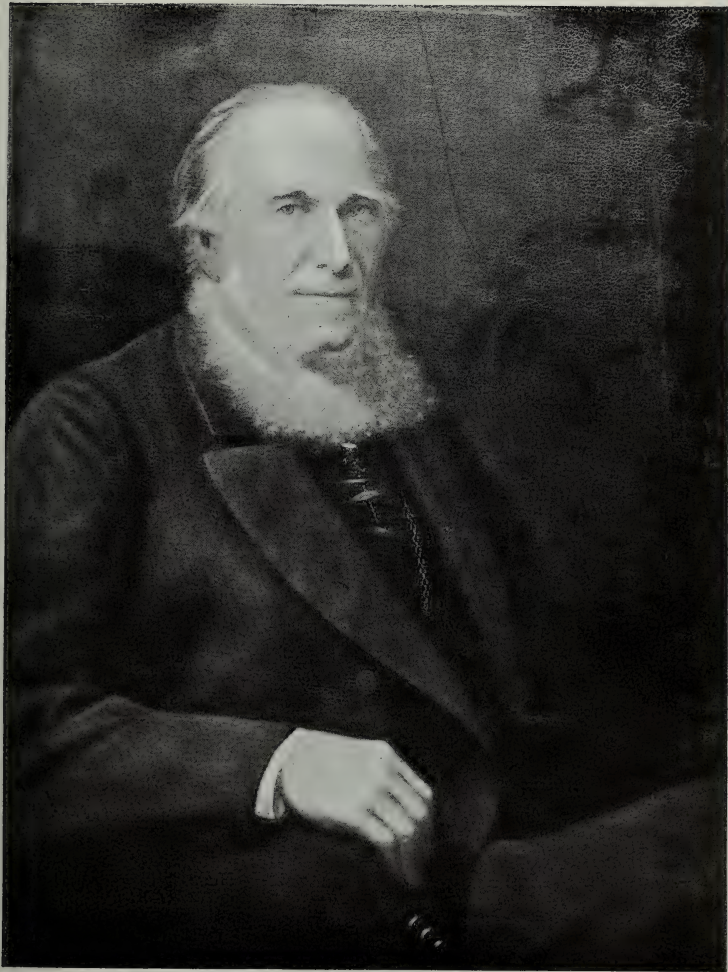
BY J. KNOX VINYCOMB.

"CRANMORE" MALONE, BELFAST,

BY J. W. CAREY.

Maryville—See pp. 67, 70 and 74.
Cranmore—See pp. 62 and 72.

From Sepia Drawings presented by Mr. A. Basil Wilson in Belfast Municipal Museum.



GORDON A. THOMPSON.

An early and frequent donor to the Society's Museum Collections. *(See pp. 81—82).*

From an Oil Painting by T. Flintoff in Belfast Municipal Museum.

Belfast, by the influence of the great Macartney family, whose agent his father had been.

The following letter from George's Dublin Uncle Thomas, dated 31st December, 1796, deals with this affair :—

"My Dear Brother,

I am conscious of the length of time elapsed since I last wrote to you, which was, I believe, the 24th October, and I am longing to hear how you are. . . . George Black, junior, has just left for Belfast, after having been a fortnight here attending His Excellency the Lord Lieutenant, this being the time his Lordship fixed for determining the business George had in view, of which you are not unacquainted. George had the honour of an audience from his Lordship on two different times, and had the satisfaction to find he had not forgot the promise he made to Lord Macartney in providing for George by appointing him a Landwaiter in Belfast, in the room of the person who wishes to resign in favour of George, on being allowed an annuity by George. This last circumstance has thrown such difficulties in the way as to retard the business for some time longer. There is an oath which cannot possibly be dispensed with, and from the nature of the agreement between George and his friend he could not comply with it. Lord Camden assured George there was no instance in which it had been dispensed with, and that he could not break through a regulation which has been so strictly adhered to."

This hesitation on George's part to commit perjury was very unusual in an office seeker of that day, the oath being regularly taken and as regularly evaded some how. The difficulty was got over later, aud George received the appointment and did his duty in it for many years. It is evident that his marriage was a happy one, and I shall quote a letter written by him from Dublin to his wife, dated 15th June, 1802,

"My Dearest Ellen,

This is no doubt a busy day at Stranmillis, for from the excessive heat all the bees will swarm—every hour I stay here renders me the more anxious to get away, this day it is the climate of Calcutta. Our journey proved very pleasant, the first day I spent at my uncle's, fashion and folly prevail there more than ever. They have a country lodging for my uncle which all the family enjoy except himself—Mrs. A., the very reverse of what she should be, dressed in all the frippery of finery, and her child $2\frac{1}{2}$ years old never brought from nurse. She seemed to feel shame when remarking that her child did not know her, to hear that your little cherub was already acquainted with you."

He describes a visit to the theatre:—"Butler and I paid 5/5 for being squeezed into the pit. Age has no visible effect on Mrs. Siddons. She has certainly greater command of looks and tone than any other person. She represented the Princess Hermione, deserted by her lover Pyrrhus, and expressed the passions of love and jealousy in a most remarkable manner."

He has accomplished all the messages:—"I have made all my purchases, dimity, paper, bacon, and a pair of black b-c-h-s, the latter at your request. . . . That health and happiness ever may attend my dearest Ellen is the sincere and ardent prayer of her affectionate

G. B."

There are many descendants of George Black still living, none in the male line, however, about Belfast. The little cherub mentioned in the letter was George Macartney Black, who took holy orders. He left a number of successors, a daughter, Emily Marguerite, becoming Mrs. Richardson of Lambeg, who died not very long ago, leaving several sons and daughters. The Blacks and Clarkes were again united by the marriage of Ellen with E. H. Clarke, who died in 1889, leaving a number of descendants.

Ellinor Stewart, George Black's wife, had four sisters; Jane, who married Walter Wilson, grandfather of Walter and Basil Wilson, both well known in Belfast. Walter Wilson was at one time the tenant of Stranmillis, thus occupying an estate which had many family memories. Mr. A. Basil Wilson remained in Maryville, where I knew him well; as also in his profession of engineer before, during, and after his management of the old Rowan Foundry in York Street. I shall have something to say later of the Wilson family. The sister, Mary Stewart, became the wife of the Rev. John Clarke, curate of Belfast, who died in 1799, worn out by his labours on behalf of charity and the people of Belfast. The sister, Annabella, married Rev. J. Trail Sturrock, of Seapatrick, near Banbridge, and this family were progenitors of the Reades of Wilmont, so well known in the life and trade of Belfast.

It is time now to say something of these Stewarts, as the Ballydrain family is one of the most interesting of old Belfast.

The Stewarts of Ballydrain.

The Stewarts were believed to be of the family of Lord Garlies, but the several versions of the connection are inconsistent. One of the Stewarts of Garlies, John, grandson of Sir Alex. Stewart of Garlies, came to Ireland and settled in Ballymoran, which property was afterwards purchased by his family. Upon the Ballymoran ground was the townland of Ballydrain, the townland of the black-thorn, and it is really probable that the name Ballydrain was adopted for the present property by the Stewarts, who built the bawn in 1608, as belonging to family tradition. It is almost certain that the ancient Ballydrain was that at Ballymoran, and is that connected with the legend of St. Mahee, which may be briefly told as follows (see page 36 of Father O'Laverty's book on the diocese) :—

Mahee was cutting timber, and when his load was finished sat down to listen to a bird singing on a blackthorn. He entered into conversation with the bird for a time which seemed an hour,

At the end of the hour he took up his load of wood, and soon after found that his conversation had lasted 300 years.

George Stewart, in 1738, tells the story of the family as follows :—

"My grandfather, William Stewart, settled at Ballydrain in the year of our Lord 1608. When the forty-one warre broke out his eldest son, William Stewart, lived in Tyrone with Sir William Stewart, great-grandfather of Lord Mountjoy. My uncle was the first express who was sent from this Kingdom to give an account of affairs to King Charles I, who was then at Edinburgh. The King sent him commissions for raising five regiments to Lord Hamilton, Montgomery, Lord of Ards, Sir William Stewart and Sir James Stewart. Sir William Stewart lost his life at the Break of Dunbar ; at that time the armye made use of match-locks. General Leslye treacherously sold the King's armye to Cromwell. The evening before he gave orders to all the armye to put out their matches, which was done by all except Colonel Ladin. This narrative I have from my own kinsmen, who were there.

Belfast, 1738. G. Stewart."

The following is another extract from the records of Ballydrain, which seems to be in the handwriting of Mrs. Sturrock:

"About the year 1640 Miss Anna Wilson, daughter of the Laird of Croglin (near Dumfries) came on a visit to some relative in Ireland, attended by a trusty servant. She landed at Donaghadee, and on her way to Dublin reached the small Inn of Drumbeg intending to pass the night there. But not finding accommodation the landlady proposed that she should go to Mr. Stewart's of Ballydrain, who she knew was absent from home at that time, and that she would apply to his housekeeper who she knew would oblige her. They proceeded accordingly and met with every kindness. But in the middle of the night the young master of the house unexpectedly returned and on being told of what had taken place desired to see the young lady though

asleep. This one vision in those days of romance was sufficient to determine him to follow her, which he did and brought her back to be his wife."

This is the first introduction of the Wilsons of Croglin into the Stewart family, afterwards completed by a marriage to be described as happening a hundred and fifty years later.

The Stewart mentioned above was John, the son of the William who built Ballydrain. He was born in 1621 and died in 1691. His wife Ann Wilson, was two years older and died in 1682.

Their son, Thomas Stewart, of Drumbeg, who was born in 1660 and died in 1715, was the member of the family who passed Ballydrain property to his descendants. His son, John Stewart, of Drumbeg, Linen Merchant, was born in 1701 and died in 1784. He married Jane Legge, of Malone, and a short notice of her ancestry may be interesting.

The Legges were an English Family of some consequence, one of whom came to Ireland with Sir Arthur Chichester, leaving Devonshire to take this service. I quote the family tradition :— "The Legges had been of service to King Charles I, and on this account King Charles II wished to reward the Legge who had settled in Ireland, but he declined to return to England. A younger member of the family, however, crossed over, and was created Lord Dartmouth, from whom the Dartmouth family is descended."

From the union of William Legge and Mary Eccles there were born a son and two daughters, who come into our story. The daughter, Elizabeth, married her cousin, William Clarke, in the direct line of the Clarke family. Elizabeth died in 1724, leaving a son, John, who in 1760 married Catherine Coates, a granddaughter of Edward Harris, and brought this name into the Clarke family. Elizabeth Legge's brother, Alexander, was great-grandfather of the Miss Legge of Malone, who became Viscountess Harberton. The first house of the Legges at Malone was built upon the ground then known as Castle Hill, which had

been the site of one of the forts, or rather bawns, which had been erected in Chichester's time around the two counties. Another sister of the old Legge family, born in 1698, married John Stewart, three years younger than herself, and became the mother of several sons and daughters. Thomas, born in 1728, married Sarah Harris, a daughter of the Edward Harris already mentioned in connection with the Clarke family, and lived at Whitehouse. Ellinor, born in 1726, died unmarried. She built Windsor, Maryville and Myrtlefield, and at her death left the Maryville property to her niece, Ellinor, who had married George Black. Robert Stewart, born in 1742, married in 1769 Mary Isabella Mitchell, and passed on the Stewart inheritance of Ballydrain, while Martha, born in 1731 married Israel Younghusband, whose daughter Jane became the wife of Nathaniel Magee of Newbridge, now Lismoyne, who has been mentioned in a pamphlet published lately by Mr. F. J. Bigger.

Mary Isabella Mitchell, married at eighteen, seems to have been a most lovely and charming girl, and a most amiable wife and loving mother.

The following notice of the marriage appears in the Public Gazetteer of December 19th—23rd, 1769 :—

"Married last week, Mr. Robert Stewart, of Ballydrain, Co. Down, to Miss Mary Mitchell, daughter of Mr. George Mitchell, an eminent tobacconist of Skinner Row."

The beauty and grace of the young girl called forth an acrostic dated May 20th, 1768, from the Rev. Joseph Weld, Archdeacon of Ross.

"Much boasts the world of Spartan Helen's charms
A fatal fair that set the world in arms.
Rejoice, Ierne, here we see combined
Youth, wit and beauty with a manly mind."
Mildness and sense well tempered mark the fair,
In vain the flatterer's voice assails her ear.
Truth, simple truth, with tenfold charm appears,
Chaste as that truth itself which she reveres.

Her breast can no transparent crystal need ;
Each heavenly virtue's seen in every deed.
Let others boast of some new conquest chained ;
Let hers be to retain those hearts she's gained."

Mary Isabella Stewart died early, aged only 34, but was long held in remembrance by her many friends. From a Belfast paper of 6th December, 1785, I extract this notice of her death :

> "Died, on Friday last, after a tedious illness, which she bore with uncommon resignation and fortitude, Mrs. Mary Isabella Stewart, of Ballydrain, leaving her friends and all who knew her to lament the loss of a woman who stood unrivalled in everything that makes the sex beloved and admired, possessed of every virtue that could adorn human nature. She has left to the world an example which the few can equal, all should endeavour to imitate."

"Fair like the snowy beauty of thy mein,
The unsullied whiteness of thy soul within.
Oh, thou hadst all that can the soul engage,
The face of youth, chastened with sapient age ;
Gay without lightness ; grave yet not severe,
Polite as courts are and as truth sincere,
Perfection all (as far as mortals can),
As soft as woman and as wise as man."

The foregoing is taken from a copy by Annabella Sturrock, then in the possession of the late R. H. Reade.

The "blind engineer," Alexander Mitchell, the inventor of the screw pile, was a nephew of this lady.

Robert Stewart left only one son and five daughters. The son, George Alexander, married Matilda Rainey, of Greenville. After his uncle's death he sold Ballydrain and removed to Macedon, which he had inherited from him. He died in 1805, and his widow afterwards became the wife of Hamilton Rowan. Four of his sisters have already been mentioned ; a fifth girl, Mattie, otherwise Helena, died unmarried.

I print one or two of her letters, showing her charming personality. Good hearted, lively, sharp-tongued Mattie Stewart, alive to me though she died in Bath 115 years ago.

Robert Stewart's brother, William, built Wilmont, but it only remained a Stewart possession for two generations, his successor having to sell it owing to financial reverses. It later came into the family of the Reades, descendants of a daughter of Sturrock, so that it came back to the blood but not to the name. The Reades were and are well known in the city, the late R. H. S. Reade, Esq., bearing the memory of the family in his name. One of William Stewart's daughters, Eliza, married John Bellingham, of Castlebellingham, and after her death her husband chose her cousin Kate Clarke as her successor.

James Templeton, the father of John, married Eleanor Legge, one of the family we are concerned with, and thus John Templeton comes into the singular chain of family connection. John Templeton was one of the great botanists and naturalists of the time. He lived at Cranmore, where he acclimatised very many rare plants, shrubs and trees. John was born in Bridge Street in 1766, and was educated by the famous David Manson. He began to study plants in 1790, after his father's death, chiefly concerned with problems of cultivation in Cranmore, in which he was always singularly successful. In 1793 he laid out an experimental garden. Later on he became the familiar friend of all the great botanists of the day. It was in 1795 that he discovered the Irish Rose—"Rosa Hibernica," and got a five-guinea prize from one of the Dublin Societies. So well was he thought of that he was offered by Sir Joseph Banks what was then a large salary and a free grant of land to go out to Australia for work there. Dr. Thomas Taylor says of him—"I believe thirty years ago his acquirements in the natural history of organized beings rivalled that of any individual in Europe." He had a singular facility with pencil and brush, and his delineations of plants and birds were surprising in their fidelity. He contributed the notes on Natural History to the Belfast Magazine, started in 1808

He was our first honorary member when our Society was founded in 1821, and on his death a medal was struck in his honour and awarded as a prize. He married in 1799, Katherine Johnston, of Seymour Hill, and left a son Robert, a medical man, deputy inspector of hospitals, and an entomologist who contributed several papers to the Magazine of Natural History.

The Clarkes have already been mentioned as descendants of the Eccles family. The present Clarkes trace descent through Mary Pollock, their grandmother, to Jeremy Taylor, through their mother to the Blacks, and by their father's family also to the Legges. Some interesting and historical connections are found in the family of which their grandfather William Clarke was a son. His sister Elizabeth married Dr. James MacDonnell the famous Belfast Physician, and one of the principal members of the old Belfast Literary Society, the father of another well known Belfast man Dr. John MacDonnell. Another sister married a Mr. Carson, and was grandmother of the Miss Cunningham who married James Thompson, of Macedon. A third sister Grace, married the rather notorious Councillor William Sampson, and a daughter of this marriage became the wife of Theobald Wolfe Tone. One of the brothers, Rev. John Clarke, was the husband of Mary Isabella Stewart, whose daughter Katherine, as I have already said became the second wife of John Bellingham. There are many other family relations to Lindsays, Stewarts, Corrys and Thompsons which I cannot deal with. Another of the Legge sisters, Jane, married Robert Thompson and became ancestress of the Thompsons of Jennymount, to whom I shall refer later.

I come now to the Jane Stewart who married Walter Wilson. I have already told you of the old connection, between 1740 and 1750, between the Stewart and the Wilson families. Robert Stewart and his wife were visiting Scotland, and as they were near the Wilson property they sent to the house asking for the Laird of Croglin. He was out at the time, but hearing later of the matter, he followed the Stewarts, and found them exceedingly agreeable friends. Some of his daughters were

invited to Ireland, and on the death of the Laird the young heir Walter was brought over to learn the linen trade at Ballydrain. While there he was lodged at Newbridge, afterwards Lismoyne, where he was an especial favourite of Nathaniel Magee's first wife, who was Stewart by blood through her mother. He fell in love with and five years later married Jane, living first at Ballydrain and afterwards at Maryville. I have already mentioned his descendants Basil and Walter, and we have as a member of the Society Mr. Alec Wilson, of Croglin, the son of the second Walter and the great-grandson of Jane Stewart.

I propose now to read you a few of the old family letters, and shall choose first, as showing the nature and difficulty of travel at the time, a letter of Mrs. Mary Isabella, wife of Robert Stewart, written from Whitehaven and dated—

"Sunday, 29th August, 1784.

My Dear Sister Ellen (Miss Ellinor Stewart, of Ballydrain).—I make no doubt you received an account of our jaunt to Donaghadee from John, and of our very uncomfortable situation there in the worst inn in Ireland. Mrs. Moorehead came to visit us and invited us to tea, where we went, but we were scarcely half-an-hour in the house when we were summoned aboard. We made ready as fast as possible and embarked about 8 o'clock.

I very soon grew sick. As the cabin was very small I determined to keep the deck; accordingly, I had a bed made with some hay covered with an old sail. On this I lay until about 12 o'clock, when the wind increasing Robert insisted on my going down below into the hold, where Mrs. Turnley and M. T. G. had been for some hours. As I was by this time totally unable to assist myself either with hands or feet, Robin and one of the men lifted me up and deposited me in the hold like a sack. But, my dear Miss Stewart, if I could give you an idea of the place where I was put by way of being comfortable—only conceive a parcel of large cobble

stones, on which was shook a little hay. On this *soft* bed I was laid down, and there continued in a state not to be described during the remainder of the voyage; but the worst is yet to come.

We arrived at Whitehaven after just 18 hours, and were there obliged to lie at anchor five hours waiting for the tide to bring us in to the pier. To give you a description of the last scene is impossible, for the tide coming in made the vessel roll and toss with double velocity, which you may well judge did not settle our stomachs. Robin had prepared two of the men to carry me, but the view I got of the long flight of narrow stone steps which we had to ascend to the quay made me exert myself to try my own limbs, and, thank God, I was able to walk safely to the inn.

As for my companions I do not know which was worst. Robin alone was able to keep his feet though he was sometimes extremely sick. Indeed, if you can imagine how busy he was in attending to us poor objects, and ordering the men by turns, you would think he never should have arrived here but for his exertions. Poor Mr. Turnley was like a dead person the whole time: he got into a small boat which was on the deck and lay on one side without stirring or speaking for 23 hours. Mrs. T. and Jenny Gairey were both so frightened that it frequently drove away their sickness; the former in particular often surprised me by bouncing up out of a severe fit and calling them to lower the sails and various directions which I now forget. Indeed she put me much in mind of the description you gave of her when the French landed.

I can't tell you how I am this morning, I am as sore as if I had been pounded in a mortar, and so weak that I can hardly walk, but Mr. Turnley and Robert are so entertaining they just keep me alive."

The rest of the letter is interesting, but we have no time to give to it. The Turnley family was of Drumnasole, near Cushendall, and the name remains yet among our shareholders.

In 1798, at the first occurrence of trouble Walter Wilson carried off to Scotland his wife and children and some of the Stewart girls to get them out of the way. Permits for travelling had to be obtained and Mr. Alec Wilson has that issued for this journey by General Goldie. It reads as follows —

"Permit Mr. and Mrs. Wilson and family with Miss Stewarts, who are of Mr. Wilson's family, to pass into Belfast, whence they wish to go to Scotland where Mr. Wilson's property is

Permit Mr. Wilson's baggage to go with him.

Lisburn, 9th June, 1798. THOMAS GOLDIE, M. GENERAL.'

I quote from the letter written by Helena Stewart to her aunt on her arrival in Scotland.

"Stranraer, 13th June, 1798.

My Dear Aunt,

We are safe and sound in this town, but, our great trouble is about our friends in Ireland. We have heard good news to-day that Belfast and the County of Antrim is all quiet. . . . . . . none of us was sick but me and nurse and the children. We have met a good many acquaintances here. Mr. and Mrs. Black are staying here now and the Younghusbands. The town is so crowded that it is almost impossible to get any sort of a lodging. We intend to stay here for a few days as it is near Portpatrick and we can hear news from Ireland sooner. I hope you and uncle will take care of George ; before we left home he promised to go into Belfast till the country would settle. I trust the Great Guardian will protect him in the hour of danger."

George was her brother, 20 years of age, who a year later married Matilda Rainey, and family affection between brother and sisters was exceedingly strong.

Three weeks later George is writing from Belfast to his sister Ellen.

"New Grove, 5th July, 1798

Although I have not received a letter from you, my dear Ellen, since I wrote to you, I cannot deny myself the gratification of addressing a few lines to you, as I am sure you will be wanting to hear about the state of the country. It is now, thank God, perfectly quiet in the North, but I believe not so much so in the South. There have been great numbers of rebels killed there. I believe they are beginning to open their eyes and see that they have been deluded by designing men. In a letter which Mr. Younghusband has had from James Butler since he went home, he mentions that a plot was discovered by which all the Protestant families in Carlow were to have been unmercifully butchered, including his uncles. There were parties of rebels to have come in at a certain hour by all the avenues leading into the town, and 600 actually did come in, but they were about ten minutes too soon. Out of the 600 only about ten escaped the slaughter, and they were taken prisoners. The other parties who were advancing when they heard the firing retreated in great confusion.

. . . . . .

I think Dr. Birch's case is truly pitiable. His brother, the clergyman, was tried last week in Lisburn for sedition, and I believe had it not been on his brother's account he would have been hanged. He is only to transport himself with all his family out of the British dominions for ever. The Doctor's eldest son, I hear, was shot in the engagement at Saintfield at the head of a party of rebels; and George was there, too, but he escaped to England and was taken prisoner at Carlisle in the dress of a young lady, accompanied by his mother and one of his sisters. . . . Only conceive the father, who is in the Yeomanry, fighting on one side and his two sons on the other. It is enough to make hnman nature shudder at the thought."

George was now 20 years old, and rumour begins to fit him with a wife. His sister Matty, otherwise Helena, has returned from Scotland, and tells the news of the place to her sister Ellen, who is in Bath with another sister, Mrs. Clarke.

"Ballydrain, August 26th, '98.

My Dear Ellen,

We are once more in a fair way of being murdered. I suppose you have heard before now of them reptiles of the French being landed in the County of Mayo. It was only yesterday we heard it and all the military went past to-day. I hope there is no reason to fear now for there is such a small number of French they would be entirely subdued . . . If it was not for the thoughts of what is going forward in the world, and the stories we hear (one twentyninth part of which is not true), we are all very well and quiet, nobody ever attempts to molest us. We won't make fools of ourselves this time and run away though Walter wants us to go . . . . . . Many a time I wish you were here, but that is just selfishness that I immediately check myself and think how much happier you are there and how pleasant it is for Mary to have you . . ." She is alarmed about an intimacy between her beloved brother and a young lady she deems undesirable, and does not mince her language, "that nasty little plague, for I can call her nothing else and her beastly mother, how I do hate them both. I am quite sure it is a scheme laid between them to get George, and they do stuff his head with such notions that if he goes into any mischief it will be entirely owing to them."

She manoeuvres to keep him from such company. "we have got him kept at home this week past. One day when Mr. Y. would keep him busy in the office, another my aunt would engage him and a third we would contrive to keep him amused, but in spite of our hearts he has gone to-day on pretence of bearing news to Belfast, for Miss C——

is staying at Mr. Ferguson's, no great credit to her. We have a very pleasant neighbour now, a Mr. Ouzley, curate of Ballylesson, (he is a cousin to the one that preaches so well) he will be of great use to George. He is an uncommon good young man and George seems very fond of him, he never swears a word and hates drinking. He is here very often, and plays very well on the fiddle and understands music uncommonly well. *He* is in the secret also and schemes as well as any of us."

But this philandering did not last long, for in October 31st George has struck the real thing and is pressing hard to marry Matilda Rainey of Greenville, who afterwards became his wife. I am sorry time prevents me from quoting any more of these letters, full of gaiety, family feeling and tenderness, but I must turn elsewhere and let you know something of the memories of Miss Mary Isabella Wilson, daughter of the Walter who married Jane Stewart, and grand aunt of Mr. Alec Wilson. I regret exceedingly that so few of these memories are available. There is a tender, simple, and graphic style about them very striking and attractive. She was born in 1799, and died in 1900, and her memory ran back till she was two years old, and was well stored with events affecting her friends. Listen to an early page.

> "The longest back I can remember was walking on the track line with my mother and my Aunt Helena's maid from Newbridge (now Lismoyne) to Maryville, and some one said: "it's a long walk for a child of two." I know the look of the spot where this was said. Aunt Helena went to England with her sister, Mrs. Clarke, after this, in 1803. My two brothers and I got little silver knives to give our three cousin Clarkes the day they left Stranmillis for Bath, where Aunt Helena died after a short illness. I can recollect her playing on the organ at Maryville and the muslin dress she had on, which she afterwards made into frocks for me, to my great delight. I remember being at Ballydrain, and Matty Rainey took me out by a glass door to look at the weather cock

upon top of the house. The sweet smell of the greenhouse at Windsor as you opened the north door I can never forget, and old Miss Ellinor Stewart in her chair at the drawing-room fire. One window looked into the greenhouse, another at the lake; from the third you could see Drum Church, where I first went to Church, holding my father's and mother's hands, as I jumped along the Bell hill and heard the Church bell on a bright, Sunday morning. I was put upon a high straw stool in the Ballydrain seat, and looked over at the Malone seat where Miss Marcella Legge, afterwards Mrs. Temple, sat." . . .

There is a curious touch of character-drawing in the following:—

"Miss Stewart, of Windsor, died in 1805, also her eldest brother, Mr. Tom Stewart, of Castle Street and Whitehouse, who gave my mother some silver, two large spoons, a tankard and two salvers in an old rubber, which he bade her return. He often drove to Maryville with old Mick, standing at the back of the carriage with his gold-headed cane. I can remember Mick pushing his fat old master into the carriage."

There is a description of a death in Jennymount, which belonged to the Thompsons, doubly related to the Wilsons. They were descended from one of the Legges, and their mother was a sister of Walter Wilson, whose mother was one of the Gordons of Traquir. I quote it because of its historical interest. After the death of her sister, who had married Captain Selby Smyth and died abroad, Jane Thompson had fretted herself into a state of weakness, so Miss Wilson tells us.

"Jane was so sad that she became very delicate, and they thought the greenhouse between the sitting-rooms bad for her health, and took it away in a few years, but not until Mrs. Maule came there in 1821, on a visit and died eleven days after she arrived. As she passed through the

greenhouse she said "Oh, how beautiful," and went up to her room, never to come down. My mother sat up with her and she bade her bring her minister to visit her, which brought her comfort. She was a very holy and lovely woman. I remember the sweet smile upon her face after her death, and while my mother held her beautiful head I held her feet while she was laid in her coffin. Her eldest son and daughter were with her. She had been a play-fellow of my father, and used to say she always liked Walter Wilson. Her mother and my grandmother were first cousins, Gordons of Dumfriesshire. I only remember one of my grand aunt Gordons of Dumfries. After Uncle Thompson's death Fox Maule and his sister, Patricia, returned to Jennymount for John Thompson's wedding, in February, 1824. The crowd at St. Ann's was so great that my mother and I could not get in, and we declined to go to the wedding breakfast. Miss Maule came to Maryville for a few days. She was not present at the wedding, but staid with poor Jane. I do not know who was best man, Robert Thompson, Alex. Wilson or Fox Maule."

Mrs. Maule's husband was a Ramsey, and had taken the name of Maule with property left by General Maule in 1787. Fox Maule became by inheritance Lord Panmure, and was the much blamed Secretary for War in the Crimean campaign. I think, myself, that his work was conscientious and hard but that he was killed by the system, which was about as rotten as could be. Patricia became Lady Patricia Young, and finally Lord Panmure, on the death of the great Indian Viceroy, became Earl of Dalhousie.

One other memory, because it introduces a name of singular interest.

"Aunt Mary Gordon's brothers died in the West Indies. Robert, the last survivor, lived until after Gordon Thompson went out to see him in 1828. If Gordon had not gone my brother had intended to go, as Uncle Gordon wrote to ask a

grand nephew to go to St. Vincent's from Belfast. His brother Alexander was Governor of Montserrat, where he died. He left all his property in Prince Edward's Island to his brother Robert."

Mrs. Marshall, a daughter of Alex. Wilson's, continues the story a little—

"Gordon Thompson returned to Belfast after twelve years' travel. . . . He came to Maryville one evening every week, and delighted us all with his stories of the Rocky Mountains, Andes, &c. It was rumoured that Lady Christian Maule had refused him. Gordon Thompson was in the Belfast Town Council, and received the Queen in 1849."

I may now leave these family histories and finish by saying something about Joseph Black as the man, the teacher, and the friend.

Joseph Black was born in 1728, the fourth son of the factor and wine merchant, and, up to his twelfth year, was educated by his mother. He was then sent home to Belfast, and became a pupil, it is said, in the old Latin School which had been established and endowed by the then Earl Donegall about 1666.

This old school was built on ground belonging to the old Corporation Church, which stood practically on the river side, on the site now occupied by St. George's Church. The school stood where is now the junction of Ann Street and Church Lane, in early days known as Schoolhouse Lane. In this school many, if not indeed most, of the well-known early citizens of Belfast were educated. Mr. A. A. Campbell has drawn my attention to an article in the old Belfast Magazine of 1809, in which a friend of the family tells us that Joseph Black was entrusted for his education to "Mr. Sprott, connected with the well-known family of Maxwell, in Comber, who had educated many of the learned men of Belfast." While this is not contradictory of the tradition as to the Latin School, it at least raises a doubt which I have, up till the present, been unable to solve. I should welcome any

information which will settle a point, in itself interesting in the history of education in Belfast.

The Latin School remained in existence until the establishment of the Belfast Academy in 1786.

Whether in the old Latin School, then, or under the care of Mr. Sprott in another place, Joseph remained in Belfast until 1746, when he entered the University of Glasgow.

In the "Matriculation Album" of Glasgow University the following reference is found, under date of 1746:—"Josephus Black, filius natu quartus Joannis Black, Mercatoris in Urbe Bordeaux in Gallia, ex Urbe de Belfast in Hibernia."

Attached to the above is an editor's note, which reads:— "Born at Bordeaux in 1728, M.D. Edin. 1754, Member of Faculty of Physic and Surgery Glasgow 1757, President of that Faculty 1759-1761 and 1765-1766. Lecturer in Chemistry in the University of Glasgow 1756-1766, Professor of Anatomy therein 1756-1757. Professor of Practice of Medecine 1757-1766· Professor of Chemistry in the University of Edinburgh 1766-1799. The discoverer of Latent Heat. Was chosen in 1789 one of the six *Associes Etrangeres* of the Royal Academy of Sciences in Paris, the greatest literary honour in Europe. Died at Edinburgh unmarried, 6th December 1799."

When Joseph Black entered Glasgow University he had the good fortune to come under the influence of two men who were well qualified to direct the studies of such an enquiring and ingenious intellect, the Professor of Natural Philosophy, Dr. Dick, and later on Dr. Cullen, the Professor of Medecine and Chemistry.

Regarding his choice of a profession, Dr. Robison, who edited his lectures published in 1803, tells us "he preferred that of Medecine, as the most suited to the general habit of his studies, not foreseeing, during the happy gaiety of youth, how much he would suffer by anxious solicitude and fears in the practice of this noble art."

Black was fortunate also in his relations and friends, The mother of James Russell, the Professor of Natural Philosophy in

Edinburgh, was a sister of his own mother, while the mother of Dr. Adam Ferguson was also an aunt, and Ferguson made the connection closer by marrying the daughter of Black's sister. Of his friends later in life the more remarkable were James Watt, David Hume, John Home, Clark of Elden, and Dr. James Hutton, the real and true begetter of the Science of Geology.

After beginning the study of Medecine in Glasgow, Black proceeded to Edinburgh to complete his work there. He does not seem to have availed himself of the time in Glasgow to shorten his studies in Edinburgh, but to have taken the full classes and courses prescribed for the degree.

The thesis offered for his M.D. degree was probably the most important contribution to scientific literature ever presented on such an occasion.

The results obtained were so very surprising in their novelty and importance that appreciation was immediate, and the publication of the paper in an English form rendered it generally accessible to those interested in scientific learning. On the Continent his experiments were soon repeated and his conclusions verified, though there were some who attempted to question their accuracy, and it became evident that a new era in Science had opened. It is no wonder that, in later years, his classrooms were filled by earnest students.

Shortly after Black obtained his degree Dr. Cullen was called from Glasgow to take a professorship in Edinburgh, and there was a vacancy in the Chair of Chemistry in Glasgow. The choice of the authorities naturally fell upon Dr. Black, and he was appointed Lecturer in Chemistry. Ten years later he left Glasgow to become Professor of Chemistry in Edinburgh, succeeding Cullen, who was appointed to the Chair of Medicine.

During his term of office in Glasgow he had a great reputation as a teacher, and was a very favourite physician of that city. I cannot help quoting his editor, Robison—"His countenance at that time of life was equally engaging as his manners were attractive, so that I do not wonder that, in the general popularity

of his character, he was in particular a favourite with the ladies. I could not but remark that they considered themselves honoured by the attentions of Dr. Black, for these were not indiscriminately bestowed, but exclusively paid to those who evinced a superiority in mental accomplishments or propriety of demeanour, and in grace and elegance of manners."

Dr. Black was always of a very delicate constitution, and on every occasion of a chill or cold subject to spitting of blood, yet by care and abstemious attention to diet he maintained an equable state of health until his seventy-first year. "The sedentary life to which study confined him was manifestly hurtful, and he never allowed himself to indulge in any intense thinking, or puzzling research without his complaint being seriously increased." He found his chief recreation in the society of his friends, and the influence of these conversations is seen in the work of Dr. Black, and also in the writings of those friends. In the earlier part of my paper, for example, I have explained the relations between the Doctor and James Watt, as well as Dr. Hutton. The man had a genius for friendship, and many tokens of feeling were lavished upon him by his associates.

Joseph Black was an artist at heart. Robison tells us that —"He had a fine accurate musical ear, and a voice that would obey it in the most perfect manner. He was a very intelligent judge of musical compositions, and I never heard any person express so intelligibly the characteristic differences of some of the national musics of Europe. Without having studied drawing he had obtained a considerable power of expression with his pencil, both in figures and in landscape. His memorandum books are full of studies of this sort, and there is one drawing of an iron furnace, fitted up with rough hewn timber, that is finished with great beauty, and would not disgrace the hand of a Woolet."

I cannot omit the following naive remark, so characteristic of Robison—"Naturally, therefore, the young ladies were proud of Dr. Black's approbation of their tastes in matters of ornament."

We do not follow Black year by year of his life. The characteristic habits and features of his life have been described, and we need not expand into a biography specially dealing with the thirty-three years in Edinburgh. Some have said that he frittered away on general medical practice the time and attention which would have given to the world many great discoveries. It is not necessary to take this view. It seems apparent that, as Black grew older, the reserve of strength and of intellectual vigour beyond what his teaching required became less and less, and it was simple wisdom to confine himself to what he felt able to perform, and leave to others to press forward upon the road which he had opened.

As to the closing years of his life I again fall back upon Robison, as his description cannot be improved—"My narrative draws to a close. The infirmities of advanced life bearing more heavily on a feeble constitution gradually curtailed those hours of walking and gentle exercise which had always been necessary for Dr. Black's case. Company and conversation began to fatigue; he went less and less abroad, and was visited only by his intimate friends. His duties at College now became too heavy a task and he got an assistant. But at length even this was more than enough for his diminished strength and he was compelled to give up lecturing altogether. His only apprehension was that of a long continued sick bed; and this, perhaps, less from any selfish feeling than from the humane consideration of the trouble and distress occasioned to attending friends, and never was this modest and generous wish more completely gratified."

His great friend and relative, Dr. Adam Ferguson, tells us that, "on the 26th November, 1799, and in the seventy-first year of his age, he expired without any convulsion, shock or stupor, to announce or retard the approach of death."

"So ended a life which had been passed in the most correct application of reason and good sense to all the objects of pursuit which providence had prescribed to his lot."

"He had long enjoyed the tender and affectionate regard of

parents whom he loved, honoured and revered; with the delightful consciousness of being a dutiful son, and being cherished as such; one of a family remarkable for sweetness of disposition and manners, he had lived with his brothers and sisters in terms of mutual love and attachment. He had never lost a friend but by the stroke of mortality."

May we all receive such an epitaph from our friends, and may we all deserve it as well as did Dr. Joseph Black.

NOTES UPON SOME OF BLACK'S FAMOUS GLASGOW AND EDINBURGH FRIENDS.

John Robison, Editor of Black's lectures, born 1739, studied at Glasgow, accompanied Wolfe on the expedition to Quebec, was rated as midshipman, and employed in surveying the St. Lawrence He went to Jamaica in charge of the chronometer invented by Harrison, on the voyage to test this instrument. He became lecturer in Chemistry in Glasgow on Black's removal to Edinburgh, but went to Russia four years later, and was appointed Inspector of the Marine Cadet Corps at Cronstadt, leaving this employment to become Professor of Natural History in Edinburgh in 1773. He wrote many valuable papers for the scientific journals, but his most interesting work was a pamphlet blaming the Freemasons for all the unrest following the French Revolution.

Adam Ferguson, from 1724, studied at St. Andrews, afterwards going to Edinburgh to study Divinity. In 1759 he became Professor of Natural Philosophy, but later changed to the chair of Moral Philosophy. His chief works were the "Essay on Civil Society" (1769), and his "History of the Progress and Termination of the Roman Republic" (1783). He died in 1816, aged ninety-three.

Adam Smith, author of the "Enquiry into the Nature and

Causes of the Wealth of Nations" (1776), only needs mention, as he is so well known.

The same may be said of James Hutton, whose great book, "The Theory of the Earth," appeared in 1795.

Many of his conclusions have been disproved by later investigation, but he was the first who systematically stated the theory of the Earth, founded on observation and developed by logical deduction from the observed facts.

David Hume, the Historian, also only requires mention. His History of England was long a standard, but is not free from prejudice and inaccuracy, and is not now quoted as authoritative.

John Clerk of Eldin, was the inventor of the system of Naval Tactics known as "breaking the enemy's line," first put in action by Rodney in his famous victory over De Grasse in 1782, though Clerk had himself never ventured further to sea than a sail to Arran. This manœuvre was afterwards used with complete success by Howe, St. Vincent, Duncan, Nelson and others.

Many others might be mentioned, such as John Home, author of Douglas; Hugh Blair, whose treatise on Rhetoric was long a favourite study of Scotch divines; Dr. Alexander Carlyle, and many more for which there is no space. It is sufficient to say that all the most eminent men in Scotland were proud to reckon themselves among the friends of Joseph Black.

12th March, 1920

Professor Gregg Wilson, President of the Society, in the Chair

THE USE OF COLLOIDS IN DISEASE.

By A. B. Searle.

An interesting lecture on "The Use of Colloids in Disease," was given by Mr. A. B. Searle of Sheffield, at the Queen's University, Belfast, under the auspices of the Society. The lecture was attended by a good gathering of local medical men and pharmaceutical chemists, as well as by a number of other people. The nature of colloids was described and illustrated by a series of experiments, in which it was shown that colloidal particles are so minute that they pass readily through the finest filter papers. Some very interesting lantern slides were exhibited, these showing the remarkable germicidal properties of some colloids as well as of metals commonly supposed to be inert.

The Lecturer said medical men and chemists had long sought for a series of medicines and disinfectants which were deadly in their action on bacteria and other germs, but were quite free from any risk of poisoning human beings. In searching for this desideration very remarkable results had been obtained during the past few years of the study of a state of matter which was intermediate between that generally recognised as "suspended" in a fluid and that in a true solution, and known as the colloidal state. Many substances of widely different composition and characteristics could be obtained in this state, and their properties then differed in many ways from what would be anticipated. The particles of colloidal matter were so minute that in many instances they could not be seen with the most powerful microscopes, but by means of an instrument known as the ultra-microsope they might be

recognised as endowed with violent motion. Many factors conducive to health depended on the possession of a colloidal character; thus the purification of sewage depended almost wholly on its ability to form colloidal solution with grease and dirt. The researches of the late Henry Crookes—a son of Sir Wm. Crookes—had proved the very effective germicidal powers of elementary colloids. This was strikingly shown by a number of lantern slides of cultures of bacteria. This germicidal property soon led to their being employed as medicines as well as germicides with remarkable results. Crookes's work has been followed up by further investigations, and these have resulted in the preparation of certain well-known metals such as silver, copper, mercury, manganese, and palladium, and of such non-metallic elements as iodine and arsenic in the form of colloidal sols which are isotonic with the fluids of the human body. These researches have made available a new series of liquids of great importance in the treatment of some of the most serious diseases, including malignant disease, syphilis, rheumatism, boils, various skin diseases, etc., as well as effecting great improvement in many minor complaints. The nature and use of these new medicines was fully described and their many advantages explained. Amongst their most striking characteristics are their freedom from poisoning properties which render the same substances risky when administered in the form of ordinary solutions. On this account large doses of colloidal sols may be given with impunity, under proper medical supervision, and cures which are ordinarily prolonged are effected rapidly. One marked difference between elements in solution and in the colloidal state is clearly seen in the case of silver and iodine. Both the pharmaceutical preparation of the substances in common use stain the skin badly; but the colloidal preparation of silver and iodine are quite stainless, whilst of equally effective and often greater therapeutic value.

The advantages of such simple, powerful and yet stainless agents are obvious; and yet these are only two instances of typical

colloids. Although the first remedial germicidal colloidal metals were first prepared in 1910, the rapidity with which they and other colloidal sols have been adopted, and their extensive use in military, naval, and private medicine practice is a certain indicator of their value and of the promptitude with which the medical profession makes use of new remedies when once their value has been clearly established. Attempts to produce similar preparation were made by several German chemists, but most of the foreign preparations lack stability and are decomposed before reaching the seat of disease they are designed to cure. Some British colloidal sols, on the contrary, are quite stable and effective. It is, however, of the utmost importance that medical men should either examine the colloidal preparations for themselves or send them to some competent and wholly independent person. Various simple, yet effective, tests were demonstrated in the lecture.

The success which has attended investigations on the use of colloids as remedial agents is so great as to call for the sympathetic interest of all who can appreciate what has been accomplished, and affords a basis of hope that further developments will be still more beneficial to suffering humanity. It is probable that serum and vaccine therapy will ultimately be resolved into questions of colloidal chemistry, but in the meantime the use of colloidal solutions of certain elements appears to offer a means whereby they can be accurately prepared and administered with a higher degree of efficiency than is possible with some of the more complex synthetic compounds at present in use.

At the conclusion of the lecture, the Chairman moved a vote of thanks to Mr Searle for his interesting address and demonstration and this was cordially passed with acclamation.

25th March, 1920.

Professor GREGG WILSON, President of the Society, in the Chair.

A NATURALIST'S WANDERINGS IN NYASALAND.

By Professor ROBERT NEWSTEAD, F.R.S.

Under the auspices of the Society a most interesting lecture entitled "A Naturalist's Wanderings in Nyasaland" was delivered in the Wellington Hall, Y.M.C.A., by Professor Robert Newstead, F.R.S., the distinguished author and lecturer.

The Chairman said they were exceptionally favoured in having such a distinguished man of science to talk to them as Professor Newstead. He was distinguished as a great worker and a great writer on zoological subjects. His monumental work on the Coccidæ was the standard book on the subject, but he had published scores of other books less in size, but many of them not less in competence. Then he was distinguished as a traveller in Jamaica and Nyasaland, and everywhere his work had been brilliant. As a public servant he had done great work of a scientific nature at the front. (Applause.) He was largely responsible for modern methods of combating one of their greatest enemies in peace and war—the fly. It was part of his duty during the war to attack the fly and solve many problems of sanitation. Lastly, he took an enthusiastic interest in archæology.

Professor Newstead said it had been long his desire to come to Belfast to meet the members of that old society, whose centenary was to be celebrated soon. Proceeding with his lecture which was illustrated by unique and interesting lantern slides made from the lecturer's own photographs. Professor Newstead referred to Nyasaland as the country in which Dr. Livingstone

travelled and did so much of his work. Having explained the geographical position of the country, he next described the methods of travel to get there, and then dealt in detail with the natives and the animal, vegetable, reptilian and bird life of the country. The tetze fly was the principal subject of his investigations. This fly was the carrier of sleeping sickness, of which there were three types, that in Nyasaland being rapid, and invariably fatal. There were four factors concerned in the spread of sleeping sickness. There was the organism which caused the disease, the tetze fly which transmitted it, the big game, which acted as natural reservoirs for the parasite, though these animals did not themselves suffer by reason of its existence in their blood. Then there was man, who almost invariably succumbed, and that was a remarkable cycle.

Councillor E. J. Elliot moved a hearty vote of thanks to the lecturer for an interesting, attractive, and fascinating lecture. Tho Society was to be congratulated for having been able to induce Professor Newstead to come and deliver that lecture, and the large attendence proved that Belfast people appreciated a lecture given by a gentleman of such eminence.

Mr. Nevin H. Foster, M.R.I.A., F.L.S., seconded the motion, which was heartily carried, and suitably acknowledged by Professor Newstead.

BELFAST

NATURAL HISTORY AND PHILOSOPHICAL SOCIETY

PROCEEDINGS,

SESSION 1919-1920.

No. 4.

ANNUAL MEETINGS

REPORTS.

LIST OF MEMBERS, ETC.

BELFAST:
MAYNE, BOYD & SON, LTD., 2 CORPORATION STREET
(PRINTERS TO THE QUEEN'S UNIVERSITY).

1920.

ANNUAL MEETING.

99TH SESSION, 1919-20.

The Annual Meeting of the Society was held in the Museum, College Square North, on Tuesday evening, November 9th, 1920, the President, Professor Gregg Wilson, O.B.E., M.A., D.Sc., presiding.

The Hon. Secretary submitted the following report :—

The Council has pleasure in submitting its report for the 99th Session.

Seven lectures have been given during the year. The list of the lectures and lecturers is as follows :—

1919.

1st November. *In Museum, College Square North.*
"The North of Ireland during the Glacial Period," by Dr. A. R. Dwerryhouse, M.R.I.A., Lecturer in Geology, Queen's University, Belfast.

21st November. *In Museum, College Square North.*
"Fluctuations in the Foreign Exchanges," by Professor F. T. Lloyd-Dodd, M.A., D.Sc., Head of the Commerce Department, Municipal Technical Institute, Belfast.

11th December. *In Museum, College Square North.*
"The Dyeing of Purple in Ancient Israel," by Rev. Isaac Herzog, M.A., D.Litt., Chief Rabbi of Dublin.

1920

13th January.	*In Museum, College Square North.* "The Great Chemist, Joseph Black, his Belfast friends and family connections," by Mr. Henry Riddell, M.E., M.I.M.E., Hon. Treasurer of the Society.
10th February.	*In Queen's University.* "Catalysis, or the Speeding up of Chemical Reactions," by Dr. S. Killen Macbeth, M.A., F.I.C., M.R.I.A., Lecturer on Organic Chemistry, Queen's University.
12th March.	*In Queen's University.* "The Use of Colloids in Disease," by Mr. Alfred B. Searle, of Sheffield.
25th March.	*In Wellington Hall, Y.M.C.A.* "A Naturalist's Wanderings in Nyasaland," by Professor Robert Newstead, F.R.S., Professor of Entomology in the Liverpool School of Tropical Medicine.

Where possible, the lectures were illustrated by Lantern and Microscopic Slides, Specimens and Experiments.

Council's Thanks.

The Council tenders its thanks to the Vice-Chancellor of Queen's University (The Rev. T. Hamilton, M.A., D.D., LL.D.), for his continued interest and for the facilities which he so willingly affords by granting accommodation in the University for lectures requiring apparatus and experiments.

The Council also desires to express its best thanks to the local Press for the reports of the various meetings, and to the Lecturers for their assistance during the session.

New Members.

Some sixty new members have joined the Society, either during the year or for the coming session. The Council wishes to thank Mr. Thomas Edens Osborne for his efforts in bringing into the Society, under the new subscription scheme, a number of townsmen having interests in science, art or literature.

Deaths.

The Council has to record, with regret, the death of four members : Mr. Blakiston-Houston, D.L., of Orangefield, formerly Member of Parliament for North Down, on February 27th, 1920, at the age of 90 years ; Mr. Hector MacColl, who died on April 22nd, 1920 ; Mr. W. H. McLaughlin, D.L., J.P., of Macedon, who died on July 18th last ; and Sir John Byers, a past President (1908-1911) of the Society, who died as recently as September 20th last. Sir John took a warm interest in all that pertained to its welfare. He delivered six lectures before your Society, dealing with Ulster dialects and folk-lore. His first lecture was given in 1903, and his last in 1918.

Irish Mss.

A grant of £15 0s. 0d. has been paid to Miss Madelaine Dempsey for cataloguing the Irish MSS. in the possession of the Society. The manuscripts referred to were deposited on loan on 18th December last, in the Reference Department of the Central Public Library, where they have been much utilised by students.

Archaeological Section.

The Archaeological Section, which is now entering its fourth year of existence, under the chairmanship of Sir Charles Brett, continues to justify its formation. Extensive excavations were made during the summer at the Mound at Downpatrick, and in Rathkeltchar, and a report of these investigations will be read by

the Honorary Secretary, Mr. H. C. Lawlor, M.R.I.A., at the annual meeting of the Section to be held towards the end of the month. The membership is considerably increased, now numbering over eighty.

Hon. Treasurer's Statement.

Mr. Riddell, the Hon. Treasurer, will submit the financial statement, which has been passed by the Local Government Board Auditor. It will be seen that the debt brought about by the repairs, due to dry rot in the upper part of the building, has been wiped out.

Exchanges.

Your Council still continues to receive, in exchange for this Society's proceedings, a number of publications, both home and foreign, from kindred Societies and Institutions, many of them being of great interest and importance. A list of these will be attached to the Society's report (see pages 123—125).

Proceedings.

The method recently adopted of printing the papers periodically has been continued during the year. Copies of these are bound up at the end of the year, as Transactions of the Society for Exchange.

Election of Council.

In accordance with the constitution of the Society, the five following members retire by rotation from the Council :—Messrs. W. B. Burrowes, E. J. Elliott, H. C. Lawlor, William Swanston, and Professor Gregg Wilson, all of whom are eligible for re-election, and the meeting will be asked to fill the vacancies, and to co-opt a member in place of Sir John Byers, deceased.

The Hon. Treasurer (Mr. Henry Riddell), when submitting

his Statement of Accounts said he would like to draw attention to the fact that the Accounts were presented in the form prescribed by the Local Government Board, and that they include of course the finances of the Archaeological Section, which possesses a credit balance of considerable amount, thus rendering the ordinary balance of the Society apparently more favourable than in reality. It has also to be said that the Society's Printers have this Session furnished no account, which will be fairly large, so that if this account had been included there would have been still a debit balance against the Society. Considering, however, the very heavy expense due to the extensive repairs of the buildings a year or two ago, the present condition of the finances must be considered very favourable. A copy of the Archaeological Section Account will be found on page 122.

ADOPTION OF REPORTS.

The President (Prof. Gregg Wilson), in moving the adoption of the reports, said that although they were commencing their hundredth year they were showing no signs of decay, but on the contrary were in a healthy flourishing condition. They could congratulate themselves on the fact that they had a good session, and at the same time congratulate themselves and more especially Mr. Deane, on the fact that they were likely to have a more successful session this year. He was delighted to know of the success of the Archaeological section, which was making a great effort to acquire the Knowles collection of antiquities. The amount of money required was rather overwhelming, but the section was going at it with vigour.

Mr. Henry Riddell seconded, and the reports were adopted.

The Late Sir John Byers, M.A., M.D., M.A.O.

The President said in view of the very special interest Sir John Byers took in the society and the great help he was to it,

it was only right that they should pass a vote of condolence to be sent to Lady Byers and family. Ever since he (Professor Gregg Wilson) came to Queen's, Professor Byers was a prominent member of the society, and was always interested in its doings. He moved the following resolution :—

> "That at this first meeting assembled since the death of Sir John Byers on 20th September, 1920, we desire to place on record our sense of the great loss the society has sustained by his death. Sir John took a deep interest in all that pertained to the welfare of the society and, during his Presidency (1908-11), the transfer of the society's museum collection to the Corporation was completed. That a copy of the foregoing resolution be forwarded to Lady Byers by the hon. secretary, and that he convey to her the society's sincere sympathy."

Mr. J. M. Finnegan, B.A., B.Sc., seconded the motion which was passed in silence, the members standing.

Life Membership.

The Hon. Secretary read letter dated 11th October, 1920, from Mr. Thomas Edens Osborne, suggesting the propriety of creating Life Members and after some discussion it was decided to leave the matter in the hands of the Council for the coming Session, to deal with.

Election of Council Members.

The following five members of Council, who retired by rotation, were re-elected on the motion of Mr. William Faren, seconded by Mr. T. Edens Osborne—Messrs. W. B. Burrowes, E. J. Elliott, H. C. Lawlor, William Swanston, and Professor Gregg Wilson.

Mr. Deane moved the co-option of Mr. T. Edens Osborne on the Council in place of the late Sir John Byers, and the motion,

which was heartily passed, was seconded by Mr. H. C. Lawlor M.R.I.A.

In moving a vote of thanks to Professor Gregg Wilson for his services during the past year Mr. Henry Riddell said he wanted to emphasise the intimate connection between that society and Queen's University. They numbered amongst their membership some of the most famous men who were also connected with the University—men whose names were known wherever the English language was spoken. Their lectures were open to the public on application to the hon. secretary or members, and the society was most anxious to accommodate the Workers' Educational Association, for which personally he had the highest admiration. One of the leading workers in that association was always a lecturer in Queen's University, and that made a practical connection between the two.

Councillor E. J. Elliott seconded the motion, which was passed with cordiality, and acknowledged by Professor Gregg Wilson.

At a subsequent meeting of the New Council the Officers were elected for the 100th Session. These together with the Members of Council will be found on page 126.

ARCHAEOLOGICAL SECTION.

Annual Meeting.

The fourth Annual General Meeting of the Section was held on Wednesday, November 24th, at 4-15 p.m., at 8 Windsor Avenue, Belfast, the residence of Mr. and Mrs. Lawlor, who very kindly entertained the large attendance of members to tea. The chair was occupied by Sir Charles Brett, who referred to the gratifying increase in the membership of the Section, which now consisted of 82. He also expressed gratification at the increased interest that had been manifested in the work of the

Section during the past season. He regretted the unavoidable absence of the Hon. Treasurer, Mr. Henry Riddell, M.E., and some other members, who had sent apologies. Mr. T. Edens Osborne, acting for Mr. Riddell, read the Treasurer's report which stated that after all expenses had been met, and the remainder of the annual subscriptions had been paid, he estimated that there would be a balance of about £75 available for the work of the Section during the coming year.

The Hon. Secretary, Mr. H. C. Lawlor, M.R.I.A., read his report. There had been three meetings of the Executive Committee held since last annual meeting. Only one application for a grant had been received, namely, one for the purpose of excavation in the Mound of Downpatrick, towards which £50 had been voted: the actual cost had been about £42. A large number of members had been present during these excavations, which had taken place in July, and to a small extent in October.

The Executive Committee had taken an active and important step towards securing for the Belfast Municipal Museum the world-famed collection of Irish antiquities of Mr. W. J. Knowles, M.R.I.A., of Ballymena. Owing to his advanced age, Mr. Knowles had come to a decision to realize this collection, and the Executive Committee have only given practical effect to the general feeling that this magnificent collection should not be allowed to leave the home of its creation. The Committee had taken the initial steps towards raising a sum sufficient to acquire the collection for Belfast, or at least preventing it being scattered by auction. The Hon. Secretary could not at this early stage—the circular explaining the matter having only been issued a few days—make any forecast as to the success of the effort.

The election of Office-bearers for the ensuing year was then proceeded with, with the following results:—

Chairman,	Sir Charles Brett.
Hon. Treasurer,	Mr. Henry Riddell, M.E.
Hon. Secretary,	Mr. H. C. Lawlor, M.R.I.A.

Executive Committee, in addition to the above, (ex-officio)

Professor Gregg Wilson, D.Sc., M.R.I.A., Mr. Arthur Deane; (elected) Mr. R. S. Lepper, M.A., F.R.Hist.Soc., Mr. Alex. Wilson, J.P., M.R.I.A., Mr. Thomas Edens Osborne, Mr. W. B. Burrowes, The Rev. William Adams, M.A., The Rev. Canon Carmody, M.A., Mr. Fergus Greeves.

The Hon. Secretary (Mr. H. C. Lawlor, M.R.I.A.) read a report upon the investigations at the Mound of Downpatrick and Rathkeltchar, already referred to, and exhibited a number of articles of great antiquarian interest discovered therein. (See pp. 105—120).

EXCAVATIONS AT THE MOUND, AND ON THE SITE OF RATHKELTCHAR, DOWNPATRICK.

About a quarter of a mile to the N. of the Cathedral of Down lies the remarkable fortified hill, to which only in recent years, the name "Rath Keltchar" or "Dunkeltair" has erroneously been applied. It will not be without interest if I briefly trace backwards in chronological order references to this mound, showing what I may call the gradual growth of this misnomer.

In an admirable and instructive little book called "The Official Guide to County Down and the Mourne Mountains" by Mr. R. Ll. Praeger, it is stated that the place is referred to as early as the year B.C. 1030, in its early form Aircealtair or Aras Cealtair, the habitation of Celtchar: but a few lines further on it states that Celtchar, or Celtchar of the battles, as he was called, was one of the heroes of the Red Branch of Ulster, and a companion of Conor McNessa, King of Ulster. Now Conor McNessa lived in the first century, A.D, so that there seems to be some confusion among the authorities as to the real origin of the name. This remarkable confusion occurs, though not in quite so pronounced a manner, in Father O'Laverty's "Diocese of Down and Connor" (vol. 1, pp. 266-7). Reeves also attributes the name to Celtchar of the battles,

but fails to explain the name as having appeared in the form of Aircealtair in 1030, B.C. (Annals F.M.). Reeves, so far as I can find, seems to have been the first writer who actually states that the Mound of Downpatrick was the Rath of Celtchar (Ecclesiastical Antiquities p. 142).

Comparing the several editions of the ordnance maps, the recent editions print the name Rathkeltchar as applying to the mound; the edition of 1857 calls it "Mount," while that of 1834, the first, merely marks it "Fort."

The Act of Parliament of 1882, dealing with the establishment of the county councils, gives the council of Down power to preserve as an Ancient Monument Dunkeltair, referring to the mound. Lewis, in his topographical Dictionary, 1837, merely refers to the mound as "the ancient doon or fort, near the church founded by St. Patrick"; he does not associate it with Dunlethglas or Rathkeltchar, from which it seems evident the confusion had not arisen in his time.

Going further back to Harris, who wrote in 1747, no sign of the confusion can be found in his account; but perhaps the clearest evidence of rather more ancient times as to the real nature of the mound can be found in an estate map drawn out in the year 1729, where the mound is marked, as then known, "The English Mount," and in the inquisition of 1662, where it is recorded that Thomas Cromwell, Earl of Ardglass, had been seized at the time of his death in 1650, of, inter alia, "Hoggs Island, Le Roundmount als Donecoscue, Courtground, &c. . . all in or near Down."*

There can be no doubt that the English Mount, Le Roundmount, otherwise Donecoscue, in or near Down, applies to the Mound as it was familiarly known in the years 1729 and 1662 respectively. In the earlier date the Norman-French name still adhered, evidently transcribed by a clerk with no accurate

*Orpen; Journal of the R.S.A.I., vol. xxxvii (1907), "Norman Motes in Ireland."

acquaintance with the ancient spellings ; but it is easy to interpret his meaning as the Round Mound, otherwise Dun de Courcy, or de Courcy's Fort.

I can find no further direct reference to the Mound of Downpatrick until we get back to the entries in The Annals of the year 1177. In the Four Masters the following occurs :—"An army was led by John de Courcy and the Knights into Dalaradia and to Dundaleathghlas ; they slew Donnell, the grandson of Cathasach (this is possibly a mistake, or another name for McDunlevy), Lord of Dalaradia. Dundaleathghlas was plundered and destroyed by John and the Knights who came in his army. A castle was erected by them there, out of which they defeated the Ulidians twice, &c." The annals of Innisfallen, however, give us more particulars of this castle of de Courcy. They record : "John de Courcy on this occasion erected a strong fort of stones and clay at Down, and drew a ditch or wall from sea to sea."* This account exactly describes the mound as it was before the flood gates at the mouth of the Quoile were erected, when the sea came round three sides of the mound ; the existing outer trench and vallum exactly correspond with "a ditch or wall from sea to sea," while the inner trench and motte and bailey are clearly the "strong fort of stones and clay."

In the following notes I adopt the terms 'motte' and 'bailey,' following the lines laid down by Mrs. Armitage in her "Early Norman Castles of the British Isles." A motte is still the French word meaning a lump or ball of earth. In Doomsday it is used to designate the mound which was always a feature of an early Norman castle, and on which a wooden tower or bretasch was built. These mottes were usually at one side of and within a circular or oval enclosure, leaving the remainder of the enclosure crescent-shaped, as in the present instance. This flat crescent-shaped enclosure was called the bailey, and corresponded

*Annals F. M., O'Dônovan ; anno 1177, note *k*.

to the courtyard of later castles. In some cases, as in Dromore, the bailey was a rectangular entrenchment with the motte outside and detached. The motte was usually built of the clay or rock excavated from a circular trench of which it became the centre. Thus the word motte or mote, latterly spelled phonetically m-o-a-t, became applicable to either a circular trench or foss, or the enclosed mound made from the soil extracted therefrom, or to the two combined. Mrs. Armitage restores the original meaning of motte, a lump of earth or artificial mound : while the moat is now more generally accepted as the trench, either full of water or dry, surrounding a habitation, such as a moated grange. The bailey or courtyard corresponds to the Irish bawn. The name is still well preserved in the Old Bailey of London, originally a courtyard of a Norman fortification. It seems to be also analogous to the Irish bally, now loosely translated as a town or townland, but really seeming to mean a populated centre or assembly of dwellings.

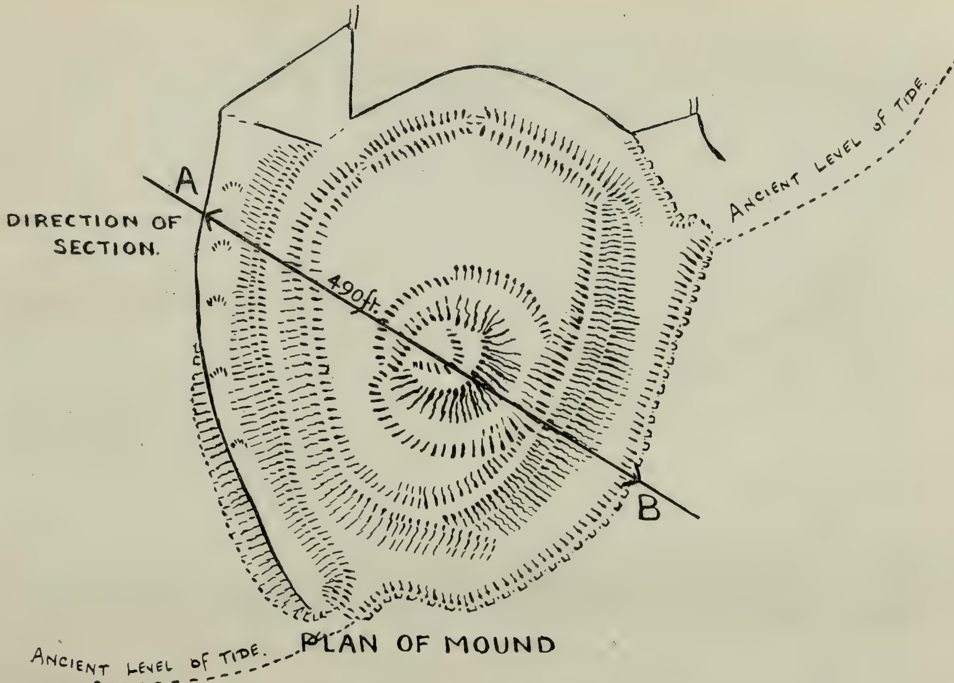
The accounts of the events immediately following the erection of this castle differ in the various annals and the account of Giraldus Cambrensis ; but one thing seems to be clear, that de Courcy having once entrenched himself here, "dug himself in," as the modern phrase is, used this fort as his rallying point. He may have suffered the defeats referred to in the annals of Innisfallen, but in the end he undoubtedly conquered Dalaradia, at first fortifying the mound as an impregnable fortification on which to fall back. This does not at all imply that his army stayed here continuously ; the Four Masters and Giraldus clearly convey that he was continuously on the move, raiding here and there, gradually increasing his hold on Down and Antrim, until finally he had the whole in subjection and "encastellated," as Giraldus relates. One thing seems to loom out clear from all accounts : de Courcy set out from Dublin with a force of a few hundred knights and well armed foot soldiers ; in four days they arrived at Downpatrick, which, all unprepared, they captured at once, erecting immediately "the strong fort of stones and clay, en-

trenched from sea to sea." How long or how continuously they camped here, or how soon their headquarters were removed to the stone and lime built fortifications in the centre of the present town, the documentary evidences forthcoming do not say; tradition indicates that de Courcy built four strong stone towers joined by curtain walls, one of these towers only now surviving, in the tower of the parish church; another stood on the site now occupied by the post-office; the two others, long since pulled down, would, with the curtain walls, have formed a large square with a strong tower at each angle.

The plan and section drawn out by Mr. Stendall, the former from the O.S. map, the latter from my measurements taken in conjunction with the map, will give an idea of the mound as it now stands. I have made a dotted line on the plan showing roughly where the tidal waters came to before the Quoile flood gates were made, as the place was in de Courcy's time. From these the importance of the particulars mentioned in the annals of Innisfallen will be apparent. The use of "the wall and ditch from sea to sea" will become evident especially to those who have studied the place in situ, bearing in mind the ancient level of the water.

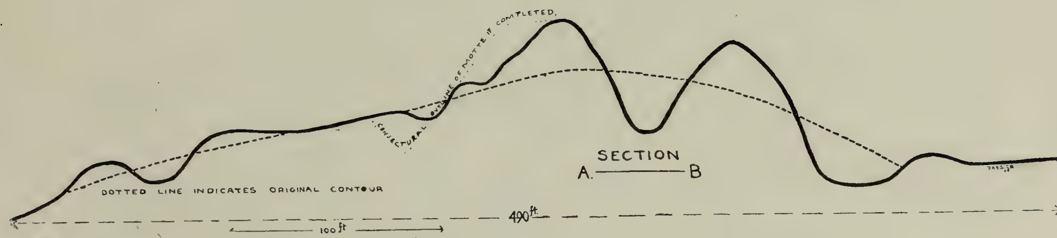
It must be remembered that the Normans under de Courcy were well armed, mail clad soldiers, expert in deadly archery, while the Irish used no armour and were ignorant of the use of the bow and arrow in warfare. The absolute impregnability of of the fort under these circumstances can be imagined. To this impregnability of the mound, scarped and counterscarped and surrounded on all sides by deep water, is probably due to the ultimate conquest by de Courcy and his knights, of the whole of Dalaradia.

In accordance with the resolution of the Executive Committee passed on 20th June, 1920, I made arrangements for excavations to be conducted in the mound. Through the active interest of Dr. T. M. Tate and Mr. S. R. Hastings of Downpatrick, a local



PLAN OF MOUND

THE MOUND OF DOWNPATRICK.



committee was formed; the landlord, Lord Dunleath, gave his consent and that of the occupying tenant was also readily given.

Through this local committee a band of ten able labouring men was engaged for the investigation, and work was started on the 13th July. Deeming the motte to have probably been the centre of activity of the fort when in occupation, we detailed four men to excavate a trench three feet wide round the crescent-shaped top; the other six men were set to work digging a trench in the bottom of the inner fosse which surrounds the motte. When these excavations were completed, and the trenches filled in and resodded, we put six men to the work of sinking pits in the bailey, and four to excavating in the neighbourhood of what was evidently a landing stage or pier on the north side when the water was at its old level. In the bailey nowhere were there the smallest indications of irregularities on the surface to indicate where hut-sites might have been; so the pits were made at random, some close to the motte, others near the enclosing vallum.

In all places the finds were few and disappointing. The total of our finds here are displayed. It is worthy of note that notwithstanding that the sides of the motte and the trench surrounding it are exceedingly steep, the topsoil lying on the bottom of the fosse is in no place more than twelve to eighteen inches deep, showing that centuries of rain and weather have not obliterated the original shape of the fort to any appreciable extent. In the bailey the topsoil averaged about eighteen inches; it was of the ordinary brown earth usual in the district, and was to all intents and purposes virgin soil, probably never tilled. At some fairly recent date it has been top-dressed, to improve the grass, and we found fragments of pottery, &c., from an ordinary modern midden or farm-yard manure heap. Such we cast aside, and the collection displayed represents all the finds exclusive of these.

On the top of the motte only a few much corroded small iron nails were turned up. In the surrounding trench were found a few pieces of late mediaeval, or even seventeenth century glass, an

antiquated iron horse shoe, some fragments of pottery of uncertain age, a few bones of large animals' and horses' teeth, the bowl and part of the stem of a pipe of early 17th century. In the bailey, where we excavated extensively, a few fragments of pottery and a few iron nails were found. At the boat quay, where we searched carefully for a refuse heap or dumping ground for waste from the camp, we found nothing but a few large nails and fragments of comparatively modern bricks and a few bits of coal. It is very remarkable that in all our excavations, either on the motte, in the trench surrounding it, or in the bailey, we found not the slightest trace of hearths, charcoal, charred wood, or soot; evidences of continued occupation were everywhere conspicuously absent.

With regard to the various articles collected during our excavations, the few iron remains convey no indication as to age, nor can we, I think, derive any information from the bones and horses' teeth; the glass is comparatively modern; there remain only the pottery fragments. I sent these to the South Kensington Museum for expert opinion, and had a courteous reply saying that the curator considered it advisable to obtain the opinion of the Department of Mediaeval Antiquities, British Museum, and that he had forwarded the collection to them. Mr. Dalton later reported that in the collection which he had examined none of the pieces seemed of earlier date than, at most, early 17th century.

I then forwarded the collection to the National Museum in Dublin, where they were carefully examined by our distinguished member, Mr. E. C. R. Armstrong, and Mr. Dudley Westropp, whose report in every respect and quite independently, confirmed that of the Department of Mediaeval Antiquities of the British Museum.

The natural deduction from the foregoing must be that the mound, fortified as it is, was never occupied to any extent by dwellers. The few articles discovered may indicate that for a brief period it may have been occupied, possibly as a camp, in the

17th century; it may have been temporarily used during the rebellion of 1641; who can say? But why did we find absolutely nothing to show ancient occupation, early mediaeval, Celtic or prehistoric? Not a trace of a hearth, not a fragment of burned wood, soot, or ash, not a flint-flake or stone weapon?

Rathkeltchar, or as it was better known, Dundalethghlas, has been a populous centre for probably 3,000 years. Our excavations in the Mound prove that it at least is not the site of an ancient settlement, and therefore cannot be Rathkeltchar, if other proof were needed. However, those who have read Mr. Goddard H. Orpen's article above referred to, and Mrs. Armitages' "Early Norman Castles in the British Isles," will have already been convinced, without our investigations, that the Mound of Downpatrick is not Rathkeltchar. It may be asked, if this is de Courcy's castle, why did our investigations discover no relics contemporary with his time? I think a remarkable feature in the motte helps to answer this: it was never even completed. The completed Norman motte was always a platform capable of holding a bretasch or wooden tower. In the Mound of Downpatrick the motte was only half made when work was suspended, leaving no place on which the bretasch could have stood.

Extracts from the several annals throw some hint as to the probably very short occupation of the mound by de Courcy. On his sudden arrival at Down, McDunlevy fled, leaving the town to be plundered by the invaders; the Irish chief hastened towards Armagh to seek for aid, and shortly returned with an army, estimated by some at as high as 10,000 men, including many clergy with sacred relics; that a battle was fought in the marshes near the town, and the Irish army disastrously defeated and dispersed, the sacred relics captured, and the clergy and many others taken prisoners, seems to be well founded. This story has been discredited and attributed to an exaggeration of Giraldus Cambrensis. I can see no reason to doubt its accuracy: the fact that the battle was fought in the marshes clearly indicates that the Irish army attacked de Courcy in his fortress, where, armed

as his comparatively few followers were, with the deadly bow and arrow, and clad in mail, of which the Irish had neither, he could have defeated twice as many. There seems to be no reason to think that de Courcy used the Mound for any length of time ; in the interval between the flight of McDunlevy and his return, the natural place for de Courcy and his followers to camp was the deserted town round the church ; on the return of McDunlevy with the army, de Courcy shut himself up in his fort, around the land side of which the battle took place. After the battle, the defeat of the Irish was so complete that probably de Courcy had no further immediate need for the fort, never finished it in detail, and had leisure to pursue adventures elsewhere.

McDunlevy seems to have been forced to make the best of a bad situation, and made peace with de Courcy, as we find indications a little later that he was in alliance with the latter in some of his raids. It is probable that it was during the period after the battle and during the peace with McDunlevy that de Courcy erected the stone castle in the centre of the town, of which the one corner tower, traditionally attributed to him, still remains.

Some three miles almost due south of Downpatrick is Castlescreen, also built by de Courcy prior to 1180. It is of almost the same design as the Mound of Down, with motte and bailey, but completed ; the oval platform of the motte measures 90′ x 27′ ; it is smaller than the Mound. About a quarter of a mile to the east of it is the stump of a stone tower of very early masonry, apparently the gate tower of a later Norman castle, where the stone tower takes the place of the early motte and bretasch.

During the progress of the excavations in the Mound I took the opportunity of examining the site of the Cathedral of Down and the surrounding ground. I was much struck with the black appearance of the earth everywhere near the cathedral, contrasting so strikingly with the natural virgin soil found on the Mound ; it seems to be thoroughly permeated with soot and small fragments of charred wood, in many places intermixed with bones. This

black soil extended not only in the immediate vicinity of the cathedral but over the fields to the south-west, west and north-west, and to the plantation on the slope to the south of the churchyard. In the field south-west of the cathedral, beyond the new churchyard extension, can still be seen remains of the old circular vallum, of which the apparent centre seems to have been near the tower of the present cathedral. This vallum is not apparent in the field to the north of this one, but can be indistinctly traced in the next field, lying N.-E. of the cathedral. Due east of the cathedral a broad roadway has been made by filling up the valley with a raised embankment ; to the S.-E. of this, and south of the churchyard, lies the old plantation, separated from the churchyard by a massive wall, built, according to local tradition, during the restoration of the cathedral in 1790 from stones removed from the old ruins. It is quite impossible now to trace the remains of the ancient vallum anywhere except in the field to the S.-W. and to a slight extent to the N.-E. ; but enough remains to show that a vallum at one time existed round the summit of the hill, with a centre somewhere near the present tower, having a radius of between four and five hundred feet. This would indicate an ancient rath with the unusually large diameter of something like three hundred yards. I learned from local enquiries that a few years ago, 1913 or 1914, I believe, immediately to the north of the present cathedral enclosure Mr. Martin, the lessee of the ground, removed a slight hill in the construction of a tennis ground, removing in the process something like an average depth of from 6 to 8 feet over an area of about three-quarters of an acre. At the time the tennis ground was being made, the County Council were engaged in raising the level of the Ballydougan Road, and arranged with Mr. Martin to remove the excavated soil to assist in constructing the necessary embankment through the marsh. During the process of the excavation, unfortunately, no detailed accounts of the many "finds" that were made were taken, and probably much that might have been of supreme interest has been hopelessly lost,

However, Mr. S. R. Hastings, Dr. T. M. Tate, and others, fortunately succeeded in preserving some of the finds, and a few items are in the possession of the cathedral verger and in the garden of Mr. Harley, which lies close to the cathedral on the N.-W. side. Mr. Hastings kindly supplied me with some notes of what he knew of the excavation, and collected together for exhibition such of the portable finds as he could now bring together. To enable us to have the account more comprehensive, we deemed it advisable to make some slight experimental excavations to find out if the foss S.-W. of the cathedral were ancient, or merely composed of refuse from the old cathedral ruin, as some supposed it to be, and also to examine more minutely the black soil, and obtain some knowledge of its nature and extent. I was not able except on one afternoon to superintend this work myself, but Mr. Hastings did so during several days in October, as weather permitted and as he could get the necessary labour.

In a most valuable Historical Sketch of the Cathedral of Down, published in 1904 by "The Down Recorder," and edited by Mr. Edward Parkinson, is a conjectural sketch of the original plan of the 13th century Benedictine Abbey of Downpatrick, by Mr. J. J. Phillips, architect. It will be of much interest to contemplate the vast extent of ground covered by the Benedictine Monastry and Church, of which only the chancel is now remaining, forming the existing cathedral, the tower being new. The foundation is ascribed to John de Courcy, during the quarter of a century he held sway in Downpatrick. It existed with fluctuating prosperity for some 350 years, from about 1188 to 1538 ; in the latter year it was absolutely destroyed by the English, whether by Lord Leonard Gray or Thomas Cromwell, Earl of Ardglass, matters little.

The excavation of 1913-14, when the tennis ground was made, was on the place marked "chapter house" and part of "the cloisters."

The results that can now be gathered of the excavation of

1913-14 together with those of our slight excavation are of immense interest. The hillock where is now the tennis ground, was composed, as to its upper layer, of refuse cast up from the ruins of the Benedictine Abbey cleared in restoring the old chancel to make the present cathedral. Many carvings in Scrabo and Dundonald sandstone and in Castleespie limestone were found ; these comprise bases and capitals of pillars, mullions, &c ; half of a piscina and various fragments of carved work. Most of these are to be seen in Mr. Harley's garden adjoining the cathedral. In this level of the hill were also found many flooring tiles of apparently early 13th century, a number of which are on exhibition. The designs are interesting, some being purely Celtic in idea ; others are early Norman. The lion rampant facing either to the dexter or sinister is much in evidence. Beneath the level of the deposit of building refuse the workers came upon the foundations of the walls of the chapter house, and it is a remarkable tribute to the accuracy of Mr. Philip's conjectural plan, that this wall was found within 6 inches of the position conjectured by him. Beneath the apparent level of the chapter house floor, immense quantities of bones, mostly, if not all, human were removed, showing that a very ancient cemetery had existed here prior to the erection of the Abbey. How ancient was this cemetery, cannot of course be accurately conjectured, but that it went far back into Pagan times was proved by the discovery of three circular drybuilt graves measuring about 5 feet deep, by 3′ 6″ wide, containing skeletons buried in a sitting position with the knees drawn up to the level of the chest. A number of bronze rings were found in or near these graves, but their exact position unfortunately was not noted down. In the tennis ground excavation no fragments of domestic or other pottery except the tiles from the Abbey debris are recorded to have been found.

In the experimental trench beginning to the east side of Hogg Island lane, and at about a right angle thereto, much of great interest was found. At the upper end the debris resembled what had been found on the surface layer of the tennis ground

site, comprising flooring tiles, roofing tiles and roofing slates from the old Abbey. With these were mixed bones and horns of domestic animals, including boars, deer and fowl, with broken pottery of the ordinary domestic, apparently mediaeval, type.

As the trench proceeded further away from the lane, the Abbey debris seemed to stop; the soil was everywhere permeated with soot and decayed vegetable matter, and very black; the depth of the black soil varied from about three feet to, at places, five or six feet or more, resting on the gravel subsoil in the neighbourhood. About 40 feet from the lane the trench cut through what appeared to be superimposed hearths showing two layers of soot or fire remains. These were traced laterally for a few feet, exposing fragments of pottery cooking vessels and several pieces of broken quern stones. The pottery of which specimens are shown is of the crude hand-made class to which I have applied the name "souterrain type"; it is the class of which about 90 per cent. of the souterrain pottery consists, and dates probably between the 4th and 8th centuries. One or two fragments of early wheel-turned pottery were also found in the black soil, but not in the hearth sites; these I believe to be of 8th to 10th century. Among the other interesting items found were two remarkable stones: one is a quartz nodule perforated by five circular polished holes; of its use I can form no conjecture. The other is an artificially rounded stone of about 2″ diameter. This is one of the hurling stones used by the Irish in warfare in the 12th century in place of the bow and arrow. Of these stones Giraldus Cambrensis says: "Handstones (*Lapides pugillares*), when other weapons fail, they hurl more dexterously than any other nation, so as to inflict great loss on their enemies." O'Curry, in his "Manners and Customs" (Vol. ii., p. 263), says that the Irish of this period retained these stones in the hollow of their shields for use when required.

The experimental excavation of the trenches just referred to was made in the latter half of October; the weather was broken and the days getting very short, so we deemed it wiser to dis-

continue further work and report the result of what we had found to the Archaeological Section for future consideration.

In conclusion I would say that from historical records coupled with what has been found by excavations, certain facts are established, which facts I may tabulate as follows :—

1. The hill on which the cathedral is situated has been a place of almost constant human occupation for at least 2,000 years.

2. It has through time been subjected to important alterations in its contour on at least four occasions, namely :—

a. The enclosure of the Rath by a vallum of which traces still remain ; date unknown.

b. The levelling of a vast area of the top for the erection of the great Benedictine Abbey, about the year 1188, when much soil was removed from the site and apparently cast over the side of the hill.

c. The clearing of the debris of the Benedictine Abbey for the creation of the present cathedral in 1790 : this debris was scattered in various places near the cathedral raising the ground considerably where it was dumped.

d. The levelling of the tennis ground on the north side of the cathedral, when about 8 feet was cut off an area of about three-quarters of an acre. The soil removed in this operation was used for raising the level of the Ballydougan Road.

3. As the hill now exists, excavations prove that its summit and to some extent its sides constitute a veritable midden of refuse of all ages from the late bronze or early iron age to the present date.

4. The hill is undoubtedly the site of the ancient Rathkeltchar, Araskeltchair, Dunkeltchair, otherwise Dunleathghlas or Dundaleathghlass.

5. The Mound is actually the entrenchment or castle made by John de Courcy in 1177 and should not be confused with Rathkeltchar.

EDUCATIONAL ENDOWMENTS (IRELAND) ACT, 1885.

The Account of the Belfast Natural History and Philosophical Society for the year ended 30th June, 1920.

Dr. | Cr.

CHARGE.

To Subscriptions		£112 19 0
,, Dividends		27 19 10
,, Rents		150 0 0
Income Tax Refunded	5 8 0	
		5 8 0
Total,		£296 6 10

LIST OF SECURITIES.

4½ per cent. Debentures York St. Flax Spinning Co.	400 0 0
5 per cent. War Loan, 1928-47	305 5 3

DISCHARGE.

By Balance as per last Account		£88 16 1
,, Maintenance of Premises, &c.		9 12 11
,, Rent, Rates and Taxes		34 0 3
,, Salaries		25 0 0
,, Other Payments, viz. :—		
Audit Fee	£1 1 0	
Cataloguing Irish MSS.	15 0 0	
Excavations	5 7 0	
Lanterns and Slides for Lectures	7 13 0	
Lecturers' Allowances	5 17 0	
Insurance	3 5 0	
Cheque Book	0 16 8	
Bank Charges	2 3 0	
		41 2 8
Advertising		34 10 4
Postages, &c.		11 17 5
Balance in Accounting Officer's hands	25 14 2	
Lodged after close of Account	25 13 0	
		51 7 2
Total,		£296 6 10

This Account is furnished in the form required by the Local Government Board. It includes the whole of the accounts of the Parent Society and the Archaeological Section. The Accouut of the Section follows separately.

We certify that the above is a true Account.
ROBERT M, YOUNG, *Governor.*
HENRY RIDDELL, *Accounting Officer.*
31st day of July, 1920.

I certify that the foregoing Account is correct.
A. A. FLYNN, *Auditor.*
18th day of August, 1920.

IN ACCOUNT WITH THE BELFAST NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.—1919—1920.

ARCHAEOLOGICAL SECTION.

	EXPENDITURE.	Amount.		REVENUE.	Amount.
June, 1920—	Expenses of Collection and Stamps ...	£1 19 0	July, 1919.—	Balance with Parent Society ...	£63 18 10
,,	One-Third Audit Expenses ...	0 7 0	June, 1920.—	Interest allowed, two years ...	5 0 0
,,	Rent of Library	0 12 0	,,	Sectional Subscriptions	19 2 0
,,	Excavations	5 7 0	,,	Subsidy from Parent Society ...	13 15 0
,,	Balance in hands of Parent Society ...	93 10 10			
		£101 15 10			£101 15 10

NOTE.—Some payments made on behalf of the Archaeological Section have not yet been segregated from Accounts furnished to the parent Society. The amounts are, however, not large, and will not cause any serious change in the statement given above.

EXCHANGES.

AUCKLAND—Annual Report of the Auckland Institute and Museum, 1919-20.

BASEL (Switzerland)—Verhandlungen der Naturforchenden Gesellschaft in Basel, 1918-19.

BELFAST—Proceedings of the Belfast Naturalists' Field Club, 1919-20.

BERGEN (Norway)—Publications of the Bergen Museum.

BIRMINGHAM—Proceedings of the Birmingham Natural History and Philosophical Society, 1919-20.

CALCUTTA—Memoirs of the Geological Survey of India.

,, Records of the Geological Survey of India.

,, Report of the Progress of Agriculture in India, 1918-19.

CAMBRIDGE (U.S.A.)—Bulletins of the Cambridge Museum of Comparative Zoology.

CAMBRIDGE—Proceedings of the Cambridge Philosophical Society.

DUBLIN—Economic Proceedings of the Royal Dublin Society.

EASTBOURNE—Transactions and Journal of the Eastbourne Natural History Club, 1914-19.

EDINBURGH—Proceedings of the Royal Physical Society.

,, Proceedings of the Royal Society of Edinburgh, 1918-19.

,, Transactions and Proceedings of the Botanical Society of Edinburgh.

ESSEX—The Essex Naturalist. Vol. XIX, Parts 2 and 3.

GLASGOW—Proceedings of the Royal Philosophical Society of Glasgow, 1917-18.

,, Transactions of the Geological Society of Glasgow, 1917-18.

GOTEBORG (Sweden)—Proceedings of the Societas Scientiarum et Litterarum Gotoburgensis, 1911-17.

HALIFAX—Proceedings and Transactions of the Nova Scotian Institute of Science.

HULL—Scientific and Field Naturalists' Club. Vol. IV—part V.

INDIANA—Proceedings of the Indiana Academy of Sciences, 1916-17.

LIMA (Peru)—Boletin del Cuerpo de de Ingenieros de Minas del Peru.

LONDON—British Museum, Economic Publications.

,, Quarterly Journal of the Royal Microscopic Society.

,, Memoirs of the Royal Astronomical Society.

,, Proceedings of the Royal Institute of Great Britain.

,, Quarterly Journal of the Geological Society.

,. Report of the British Association, 1918.

LOUSANNE—Bulletin de la Societe Vaudoise des Sciences Naturelles.

MADRAS—Report of the Government Museum of Madras, 1918-19.

MAINE—Bulletins of the Maine Agricultural Experiment Station.

MANCHESTER—Journal of the Manchester Geographical Society

MELBOURNE—Proceedings of the Royal Society of Victoria.

MEXICO—Anales del Instituto Geologico de Mexico.

MICHIGAN—Report of the Michigan Academy of Science.

NEW HAVEN—Transactions of the Connecticut Academy of Art and Sciences, 1920.

NEW YORK—Annals of the New York Academy of Sciences.

,, The Geographical Review (Monthly).

OHIO—The Ohio Journal of Science.

OTTAWA—Memoirs of the Canadian Geological Survey.

,, Memoirs of the Geological Survey of Canada, Department of Mines.

PADOVA (Italy)—Atti della Accademia Scientifica.

PHILADELPHIA—Proceedings of the Academy of Natural Sciences of Philadelphia.

PISA (Italy)—Atti della Societa Tescana di Scienze Naturali.

REIGATE—Proceedings of the Holmesdale Natural History Club 1914-19.

RIO DE JANEIRO—Report of the National Museum of Brazil.

SAN FRANCISCO—Proceedings of the California Academy of Science.

ST. LOUIS—Public Library Monthly Bulletin.

TORQUAY—Journal of Torquay Natural History Society.

TORONTO—Transactions of the Royal Canadian Institute.

UPSALA—Bulletin of the Geological Institution of Upsala University.

WASHINGTON—Annual Report of the Smithsonian Institution.

" Annual Report of the United States National Museum.

" Bulletins of the Bureau of American Ethnology.

" Bulletins of the Smithsonian Institution.

" Contributions from the United States National Herbarium.

" Proceedings of the United States National Museum.

" Smithsonian Institution, Miscellaneous Collections.

" Year Book of the United States Department of Agriculture, 1919.

" Bulletins of the United States Geological Survey.

YORK—Annual Report of the Yorkshire Philosophical Society, 1918-19.

ZURICH (Switzerland)—Vierteljahrsschrift der Naturforchenden Gesellschaft in Zurich.

BELFAST NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.

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Proceedings and Reports

1920-21, Nos. 1 to 3.
With 3 Title-Pages
dated 1921.

OF THE

BELFAST

Natural History and Philosophical Society

FOR THE

SESSION 1920-21.

BELFAST:
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BELFAST NATURAL HISTORY and PHILOSOPHICAL SOCIETY.

[ESTABLISHED 1821].

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The membership of the Society consists of Shareholders, Annual Subscribers, and Honorary Members.

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In 1914 **a new class of membership** was created including persons of either sex, to be elected under the bye-laws of the Society, and admitted by the Council on payment of ten shillings per annum. Such members have all the privileges of the Society, and take part in any business of the Society not affecting the ownership of the property of the Society. In 1917 an Archæological Section was founded. Persons wishing to join the Section must be members of the Society and pay an additional minimum subscription of five shillings per annum. An Application Form for Membership to the Society and to the Section will be found on page vii.

A general meeting of Shareholders and Members is held annually in June, or as soon thereafter as convenient, to receive the Report of the Council and the Statement of Accounts for the preceding year, to elect members of Council, to replace those retiring by rotation or for other reasons, and to transact any other business incidental to an Annual Meeting.

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Each member has the right of personal attendance at the Ordinary lectures of the Society, and has the privilege of introducing two friends for admission to such. The session for lectures extends from November to May.

Any further information required may be obtained from the Hon. Secretary at :—The Museum, College Square North, Belfast.

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BELFAST
NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.

PROCEEDINGS,

100TH SESSION 1920-1921.

No. 1.

5TH OCTOBER, 9TH NOVEMBER, 14TH DECEMBER, 1920.

MANY INVENTIONS: A STUDY IN NATURAL HISTORY
BY PROFESSOR J. ARTHUR THOMSON.

THE TREND OF EVOLUTIONARY THOUGHT.
BY PROFESSOR GREGG WILSON.

THE BIRDS OF HILLSBOROUGH.
BY NEVIN H. FOSTER, F.L.S., M.R.I.A., M.B.O.U.

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1921.

5th October, 1920.

Professor GREGG WILSON, President of the Society, in the Chair.

PUBLIC LECTURE by Professor J. ARTHUR THOMSON, M.A., LL.D., Entitled:

"MANY INVENTIONS: A STUDY IN NATURAL HISTORY."

(*Abstract*).

Professor Thomson, in the course of his very interesting and instructive lecture, said there is a quality of endeavour in the majority of living creatures. They are always attempting the apparently impossible and achieving it. Of some, it may be said that they seek the line of least resistance, and drift into a parasitic or saprophytic life of ease, but that is not the way of the majority. Of animals especially it must be admitted that they have the will to live, and to live in a particular way, which is oftener against the stream than with it. We see this quality in prolific multiplication (one of our British starfishes has 200 million eggs); in the multitude of different species (quarter of a million backboneless animals named and known); in longevity (the centenarian parrot and the Big Tree that lived for over two thousand years); in the conquest of space (Arctic Terns within the Antarctic Circle); in circumventing the seasons (by migration or by hibernation); in exploiting inhospitable areas such as the dark abysses of the ocean.

But there is another quality of living creatures for which it is difficult to find a name unless it be *inventiveness.* They show what look like ingenious ways of meeting difficulties, what look like devices and inventions. The puzzle is that these are often exhibited at levels where we dare not suppose we are dealing with deliberately-thought out devices. An example of the

biological problem may be found in the case of the partnership between hermit-crab and sea-anemone. The hermit-crab, having a fairly well-developed brain may be appreciatively aware of what he does when he puts a partner, sea-anemone, on his back, but what are we to say of the more than acquiescent partner which has no nerve-ganglia at all?

At the lowest level we have the behaviour of the Bryony binding itself to the hedgerow, the Venus Fly-Trap shutting on the insect, the starfish surrendering an arm and thus saving its life, or the sea-anemone creeping up the hermit-crab's leg. There are inborn structural and functional adaptations which work effectively when the trigger is pulled. In the absence of any nerve-ganglia, we dare not use any big psychological word like perception or inferring.

At the highest level we have Rooks breaking freshwater mussels by letting them fall from a height, or the Thrush breaking the snail's shell on a stone, or the skua chivying other gulls and forcing them to disgorge, where it is perhaps warrantable to speak of deliberate intelligence, of experimental inference. But it is difficult to decide how many apparently bright ideas, like the mole's cache of decapitated earthworms, are as clever as they at first sight seem. It is difficult to know how far down in the scale we can get presumptive evidence of intelligent invention. To what extent did real inventiveness enter into the sea-swift's making of a nest out of its salivary juice, or into the neat device by which the snake, Dasypeltis, breaks the birds' eggs which it swallows, or into the extraordinary fashion in which Darwin's frog rears its young ones in its croaking sacs, or into the way in which the male of the New Guinea Fish, Kurtus, carries his family on the top of his head. The testing and trying of new peculiarities of structure and of function—new departures arising as germinal variations, might lead to the racial establishment of inventive devices which were intelligently appreciated and approved of by the animal, though they were not intelligently thought out or devised.

But between the lower level, covered perhaps by the concepts of structural adaptiveness and general endeavour to find equilibrium and satisfaction, and the higher levels where plastic intelligence holds the reins, or did in the past play the cards supplied by germinal variations, there is the large and puzzling field of what may be called *instinctive* inventiveness.

The tailor ants use their larvæ to supply the thread for their sewing; a common harvesting ant of South Europe makes biscuits of chewed seeds; a few ants go far in the direction of domesticating Aphids; many Termites grow moulds on specially constructed beds; the cuckoo-spit saves its life by blowing soap-bubbles; many Digger-Wasps store paralysed caterpillars for their young, which they do not survive to see; one of them sometimes uses a pebble (like a tool) in her mouth to close the mouth of the burrow smoothly; some ants and wasps have entered into a strange nutritive give-and-take relation with the larvæ of the nest; the larval tiger-beetle has an ingenious way of smashing the small insects that rest on the living trap-door of its burrow; the water-spider makes a web at the foot of the pool, though it is a member of a thoroughly terrestrial race, breathing dry air; the trap-door spider invented the hinge; the gossamer spiders make aerial journeys without wings. It certainly looks as if animals thought out many inventions.

If we can accept the view that the gains of novel individual experience, registered in the structure of the nervous system during the individual lifetime, are entailed, even in some representative degree, on the progeny, then the puzzle of accounting for the apparent inventions below the level of dominant intelligence would be lessened.

If we cannot accept the Lamarckian or Neo-Lamarckian view of the entailment of the structural results of novel or peculiar individual experiences, what then? The following theory is suggested: (1) In the germ-cells, which somehow epitomise the past, novelties or variations or mutations are of frequent occurrence,—not "anyhow" variations, however, but new

departures more or less consistent with the past. (2) These new departures, usually improvements on previous new departures, find expression in the structure and function of the embodied organism—the player, into whose hands the germinal cards are put. It is for the embodied or explicit organism, mind-body and body-mind in one, to play these cards, to test their worth, even to find the environing conditions where they will be of most avail. Unprofitable tentatives, coming from the implicit organism (the germ cell) will prove fatal in the experience of the explicit or embodied organism (the animal) and that will be an end of them. But when variations or mutations on the inclined plane of behaviour (and of course its subjective or psychical side) prove profitable when tested by the individual creature, then they will bring success which is likely to mean their entailment, for the heritability of many germinal novelties is now certain.

"It is in this way that the lower animals have profited by inborn inspirations never clearly thought out, and just as it may have taken a million years to fashion the feathers of birds, so it may have taken ten millions to endow the tribe of ants with their marvellous repertory of apparent inventions." (From "More Secrets of Animal Life," unpublished).

A hearty vote of thanks was accorded Professor Thomson, on the motion of Councillor E. J. Elliott, seconded by Mr. Henry Riddell, M.E.

9th November, 1920.

PRESIDENTIAL ADDRESS.

"THE TREND OF EVOLUTIONARY THOUGHT."

By Professor GREGG WILSON, O.B.E., M.A., D.Sc., M.R.I.A.

The doctrine of evolution is no new idea, nor is the chief modern controversy in connection with it new. I refer to the dispute between "mechanists" and "vitalists."

The ancient Greeks had more or less clear beliefs as to the fact of evolution*, and differed fundamentally among themselves as to explanation of the fact, just as we of the twentieth century do. Empedocles of Agrigentum (495—435 B.C.), who has been called "the father of the evolution idea," may be named as a type of those who explained things largely by chance. He believed in spontaneous generation of the living from the not-living; that plants came before animals; that parts of animals appeared before entire animals; and that, as a result of the triumph of love over hate, these parts united, but purely fortuitously. Most of the resulting monstrous combinations, he supposed, were unfit to live, but in time there arose by chance forms that were able to maintain themselves and multiply. It was a crude beginning, but it served as a foundation, on which Epicurus and others built up a purely mechanical conception of nature. Aristotle (384—322 B.C.) gives an account of evolution that is much more modern in character, and his explanation is distinctly vitalistic. He believed in a progressive development from a primordial soft mass of living matter to the highest forms of animals. He adopted the doctrine (now specially associated with the name of Lamarck) that characters acquired by an animal

* See H. F. Osborn: "From the Greeks to Darwin." Macmillan & Co., 1908.

in the course of its life may be transmitted to its offspring. He actually considered the possibility of the origin of new characters and new species by chance variations and the survival of the fittest varieties; and he rejected this Darwinian theory, and preferred to give credit to "an internal perfecting tendency," which was capable of driving organisms forward to give rise to more perfect types.

For many centuries the views of Aristotle were accepted. Even in the early Christian Church his ideas prevailed, and Augustine (353—430 A.D.) expressly states that the story of the Creation in Genesis should not be taken literally; that evolution had been gradual; and that even the bodily structure of man had been a product of natural development. For something like twelve centuries there was no important change in the Church's teaching on this subject; but in the 16th century Suarez and others taught that the entire work of creation took place in six days of twenty-four hours; and till the middle of the nineteenth century this was the prevalent opinion. Then came another revolution in thought, largely due to the brilliant labours of Charles Darwin; and now there is practical unanimity among educated men as to the fact of evolution. Our study of comparative anatomy; of the history that is recorded in the rocks; of the facts of adaptation to environment; of variation and heredity, all convince us of the mutability of species and the truth of the great doctrine of evolution. But as to the how and why of evolution there is very little certainty. As Driesch says: "In this field we are just at the very beginning of what deserves the name of exact knowledge."*

Modern thought on Evolution may be said to have started with Buffon (1707—1788), whose merit is that he "inspired later writers to consider the great problem."† He first pointed out on a broad scale the mutability of species in relation to changes of environment; and he laid stress on modifications

*The Science and Philosophy of the Organism, p. 21.

†Osborn: From the Greeks to Darwin, p. 137.

induced by the direct action of the environment. He knew about the struggle for existence and elimination of the least perfect. He also referred to the formation of new varieties of animals by artificial selection, and showed that similar results might be produced in nature by migration.

Erasmus Darwin (1731—1802) is the next writer who interests us greatly. He was grandfather of Charles Darwin, and was not less enthusiastic about evolution than his famous grandson. He wrote much in prose and verse, and in his writings he anticipated Lamarck in teaching that organisms vary because of their doings, and that the results of their exertions are transmitted to their posterity. He did not, like Buffon, lay stress on the direct action of the environment, but rather emphasized the idea that modifications spring from within, as a result of the strivings of the organisms during many generations. Even plants, according to him, make efforts towards certain ends.

Lamarck (1744—1829) came after Erasmus Darwin, and apparently without having read the latter's works, gave expression to the same general ideas on the evolution of animals that had been put forward by Darwin. Rather curiously, he followed Buffon in regard to the evolution of plants, believing that they were evolved by the direct action of the environment. But as regards animals he took the same view as Erasmus Darwin, holding that environment did not act directly to produce modifications, but only indirectly, through the nervous system. The essential cause of new structures was the striving of the animal. A felt want (*besoin*) led to action, and that to modification. The second great doctrine of the Lamarckian creed was that acquired characters are transmitted to offspring.

Lamarkism is regarded as vitalistic because of the psychical factor implied in the *want* that gives rise to activity; but Lamarck was strongly opposed to the old Aristotelian idea of a perfecting tendency in nature. He rather ascribed the variety and perfect adaptation of animals to the fact that the species, while spreading in all the habitable regions of the globe, have—

under the influence of environment—developed new habits and consequent modifications. We shall find, when we come to consider more recent views of evolution, that this belief in the striving of the organism in response to environmental stimulus has been revived.

A second epoch in the history of modern thought on evolution begins with Charles Darwin, whose work on the "Origin of Species" appeared in 1859. He may be said to have converted the world to belief in the fact of evolution. In his explanation of the change of species, he accepted the Lamarckian doctrines, but he added the idea of the survival of the fittest or most favourable variations in the struggle for existence. He regarded the slight differences that appear among members of a family as the determiners of life or death; and he dwelt on the fact that a variation that secured survival of an individual at the same time provided a chance that there would be offspring of that individual, with its useful characteristics. He changed the point of view of the scientific world, for whereas Lamarck had laid stress on modification of the body of the adult animal, Charles Darwin emphasized the importance of variations in the egg. He regarded these congenital variations as heritable, and he showed how useful modifications might be built up by successive additions, generation after generation.

Weismann (1834—1914) out-Darwined Darwin. He proclaimed the "all-sufficiency of natural selection"* and discredited Lamarckism. He maintained that there was no proof of the transmission of acquired characters, and that owing to the isolation of the germ-plasm such transmission was inconceivable. His work on the nature of the germ-plasm was most important.† He strove to show that hereditary characters are represented by definite "determinants" in the chromosomes of the germ nucleus, and that development of the egg is essentially an

* Contemporary Review, September and October, 1893.

† "The Germ Plasm: a Theory of Heredity." 1893.

evolutio or distribution of these determinants. Variation, according to him, is brought about by the mingling of germ-plasms.

The work of Gregor Mendel, published in 1865, but lost sight of till it was confirmed by three independent workers in 1900, was of supreme importance in connection with Weismann's theory. Mendel worked with peas, and showed how characters, such as yellowness or greenness, tallness or smallness, do not blend, but are alternative in inheritance ; and he further proved that such characters are represented singly in the germ-cells.* The great fact that he established, and that has been confirmed time after time, alike for plants and for animals, is that there are *definite representatives* (which we may call "determinants") of certain unit characters in the germ-plasm. His work, then, may be taken as so far confirmatory of the Weismannic theory of the structure of the germ-plasm. It has thrown light, too, on the formation of new species by combination of characters or by the dropping out of characters.

To be associated with the Mendelian view of inheritance is the recent work on heredity of sex. From this it appears that there is good evidence that in some insects one particular chromosome of the germ nucleus can be recognised as "sex determining" in character. In the bug *Protenor*, for example, the cells of the male have thirteen chromosomes, while those of the female have fourteen, and one of the thirteen is larger than the other twelve, and can be identified as "sex determining." As a result of the usual maturation processes the male germ-cells yield two types of spermatozoa, one with six chromosomes, all alike, and the other with seven chromosomes, six small and one large. The mature egg-cells, on the other hand, have all seven chromosomes, six small and one large. If a spermatozoon with six chromosomes fertilises an egg-cell, the result is a male with thirteen chromosomes in its cells. But if a spermatozoon with seven chromosomes fertilises an egg-cell, then the consequence is

* See "Mendel's Principles of Heredity," by Professor W. Bateson.

the formation of a female with fourteen chromosomes in its cells, and in every cell two are of the large type. Much evidence of this nature goes to show that sex is determined just as the Mendelian greenness or yellowness in peas are inherited.

The Darwin-Weismann school certainly is mechanistic in tendency. Its extreme disciples regard all nature as the necessary result of the "mutual interaction, according to definite laws, of the forces possessed by the molecules of which the primitive nebulosity of the universe was composed."* The present is an unfolding of the past, and the future is a certainty, and is determined by the present. The development of the individual is a mere displaying of characters contributed by the parents to the egg; but these characters depend for survival und unfolding on environmental conditions, such as nourishment, temperature, &c. Similarly the evolution of the race is an outcome of combinations of characters, fostered by natural selection. Even psychical qualities are given a mechanistic interpretation: for example, Loeb says: "I consider consciousness the function of a definite machine or mechanism, which we may call the mechanism of associative memory."†

Weismann found many followers, especially, perhaps, in Britain; but there were always many zoologists who had difficulty in accepting the rigidly mechanical account of the germ-plasm associated with his name; and others were unwilling to give up belief in the old doctrine of transmission of acquired characters.

This century seems to me to be specially marked by the perception of difficulties in the mechanistic view, and by a tendency to a revival of Lamarkism or other form of vitalism.‡

The first adverse criticism of the "Natural Selection" school that I would mention refers to the casual variations, which

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* Huxley.

†Professor J. Loeb: "The Dynamics of Living Matter." 1906. page 6.

‡ The notes that follow are not put forward as a reasoned criticism of the mechanistic school, but rather as jottings indicating generally the nature of some of the difficulties felt with regard to its teachings, and some of the recent suggestions that are on vitalistic lines.

Darwin regarded as the basis of evolution. Not a few workers have found it difficult to imagine the success of such ; and Herbert Spencer, in particular, held that it was incredible that without transmission of acquired characters there should be harmonious variation of the different parts that co-operate to produce one physiological result.

But de Vries and the Mendelians go further, for they challenge the heritability of the Darwinian variations. De Vries maintains that casual variations or fluctuations such as one finds in every family, are swamped in cross-breeding ; and he argues that new species appear all at once, by what he calls "mutation." The Mendelians provide a reason for this : they say that each individual characteristic of a species is represented by an individual determinant in the germ-plasm, and the transition from one form to another is only possible through the addition or disappearance of one or more of the characteristics. They hold that "the conception of evolution as proceeding through the gradual transformation of masses of individuals is one that the study of genetics shows immediately to be false."

So there is a considerable body of opinion hostile to the Darwin-Weismann view of the basis of evolution.

But, secondly, the Natural Selection theory does not explain the origin of the distinctively new. As Arthur Thomson says, biology seems justified in holding "that there has been a frequent epigenesis or new formation, a frequent outcrop of genuine novelties. . . . There was a time when there were no insects ; they came into being, and they were new ideas."† But Darwin offers no explanation of the new, and Weismann has not carried conviction by suggesting that the new is merely a combination of the old. T. H. Morgan puts the case fairly‡ as follows : "There is evidence to show that the germ-plasm *does* sometimes change

* Hugo de Vries : Species and Varieties : Their Origin by Mutation. 1905.

† "The System of Animate Nature," vol. II,, p. 367.

‡ "Sex and Heredity," p. 17.

or is changed. Weismann's attempt to refer all such changes to re-combinations of internal factors in the germ-plasm itself has not met with much success. Admitting that new combinations may be brought about in this way, yet it seems unlikely that the entire process of evolution could have resulted by re-combining what already existed ; for it would mean, if taken at its face value, that by re-combination of the differences already present in the first living material, all of the higher animals and plants were fore-ordained."

In this connection it is worth while to quote Bateson, our great Mendelian worker, who writes: "As to almost all the essential features whether of cause or mode by which specific diversity has become what we perceive it to be, we have to confess an ignorance almost absolute."

A third difficulty in the way of believing in the "all-sufficiency of natural selection" is found in the fact that the mechanistic theory of development by "evolutio" makes no real attempt to explain the orderly arrangement of the wonderful units that are supposed to exist in the germ-plasm. As Child says:* "The combination of these units into the individual is assumed to occur as the facts demand, and although the problem of the control and ordering of millions of such units through all the changes involved in the development of a complex organism, say the human body, is one which staggers human intelligence, it is practically ignored."

But a fourth difficulty arises from the fact that there is now good reason to say that development is *not* an "evolutio." And Weismann's whole system depends on this doctrine. Roux at one time seemed to have confirmed the view that the germ-plasm is a mosaic and development a mere displaying of characters that were localised in the egg. He destroyed one cell of a two-cell stage in a frog's development, with the result that a half-embryo developed. But with sea-urchin eggs Driesch got opposite results: one cell of a two-cell stage, or even of a later stage, was

* "Individuality of Organisms," pp. 22-23.

shown to be capable of building an entire larva. And even the frog's egg, when suitably manipulated, yields an entire embryo from one cell of the two-cell stage. Many other experiments have been made by many workers, and the result is abundant evidence in favour of the resourcefulness of the embryo and against the idea that development is to be regarded as a mere mechanical unfolding or "evolutio." As Russell says in his very suggestive volume on "Form and Function," p. 346 :—"Experimental work opened men's eyes to the fact that the developing organism is very much a living, active, responsive thing, quite capable of relinquishing at need the beaten track of normal development which its ancestors have followed for countless generations, in order to meet emergencies with an immediate and purposive reaction."

Even modern mechanists have given up Weismann's view of evolutio, and some of them lay stress, not on local determinants, but on "the capacities of the reaction system."

A fifth difficulty in regard to the mechanistic view is seen in the wonderful resourcefulness of the adult organism in circumstances that could not apparently have been provided for by natural selection. Many experiments have brought home to us the fact that organisms can deal successfully with new conditions. The well-known power that the newt has of regenerating an amputated limb might be accounted for by supposing there was a considerable reserve of supplementary determinants placed at convenient intervals along the member, but other cases are not susceptible of such simple explanation. In the case of the hydroid Tubularia, for instance, Miss Bickford has shown that the combined work of many parts is involved in the restoration of a decapitated head. And Driesch shows how the branchial apparatus alone, or even half of the branchial apparatus of Clavellina, may form a sphere, and then re-construct a small complete ascidian. And again we have the classical case of regeneration of the lens of an eye, not from the normal foun-

dation, but from the edge of the iris. Such facts certainly tempt one to conclude that organisms possess a definite purposiveness that cannot be explained by natural selection.

Lastly, I would lay stress on the fact that the mechanistic theory of natural selection does not explain the individuality of organisms, and particularly of multicellular organisms. There is an individuality which, as C. M. Child says,* "is distinctive of the living organism, which determines harmonious development and functional unity throughout the continuous dynamic change which constitutes life." Child attempts to explain this as ultimately resulting from the relations between living protoplasm and the world external to it; but he also regards this individuality as the dominant not the subordinate or casual. He recognises that the organism is a unit in inheritance and development.—not a mere assemblage of cells. And it is because of this recognition that he says we must expect to find that so-called 'acquired characters' may be impressed on the organism to such a degree that sooner or later the reaction system may give rise to these characters without the action of the particular external factor which originally produced them. An individuality of this kind is certainly not accounted for by the orthodox mechanistic philosophy.

It is not surprising that there are numerous rival theories to the Weismannic one. Oscar Hertwig has all along seen the difficulties of Weismann's view of the germ-plasm and of development, and has given credit to *position* as determining the fate of a cell in development; and others have held similar views. But while there probably never before was such appreciation of the perfection of mechanisms in the organism† there seems to be an even fuller recognition of the distinctiveness of organisms.

Some thinkers, like the metaphysical physiologist Haldane,‡ go the length of proclaiming that this world, with all that is

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* "Individuality in Organisms." Chicago, 1915.

† See Prof. D'Arcy Thompson: "Growth and Form." 1917.

‡ "Mechanism, Life, and Personality." 1913.

within it, is a spiritual world. He urges that there is not the remotest possibility of deriving the organic from the inorganic, but that in tracing life back and back towards what at first appears to be the inorganic, we are really seeking to reduce the inorganic to the organic. Professor Frederick Soddy, who looks at things with the eyes of a chemist and physicist, is equally emphatic as to the impossibility of explaining the world of life and personality as a result of the study of the world of mechanism. He regards the two as distinct. He says: "Apart from extreme opinions on such a point, I think there is a growing tendency to distinguish between the mechanism of life and its conscious regulation." And he emphasizes the fact that our knowledge of the mechanical world is of such a nature that "*from this world mystery in any real sense has been banished.*" And he adds: "One's scientific sense of direction tells that the further one advances towards the ultimate insoluble problems of physics, the more completely one leaves behind the phenomena of life and all its mysteries." He compares the organism to Niagara under control, with some of its water working turbines to which are geared dynamos: and he points out that "Niagara to-day is a mechanism as before, but it has been linked to an external intelligence capable of guiding and varying its action at will."*

Many zoologists have also emphasized the distinctiveness of the living. E. B. Wilson, for example, in his great work on "The Cell," says: "The study of the cell has, on the whole, seemed to widen rather than to narrow the enormous gap that separates even the lowest forms of life from the inorganic world." Even in the humblest manifestations of life the student discovers traces of an effective psychological activity. And physiologists tell us how many of the mechanisms of the body are regulated. "The idea," says Haldane, and others agree with him, "which gives unity and coherence to the whole of the physiology of respiration is that of the *organic determination* of the phenomena."

* Professor Frederick Soddy: "Science and Life." London. 1920.

Professor Arthur Thomson, in his recent Gifford Lectures, strives to show that mutations are "expressions of *the whole organism*, . . . comparable to experiments in practical life, solutions of problems in intellectual life, or creations in artistic life. These are accomplished, as everyone knows, by molecular activities in the brain and body, but they are not intelligibly thought of unless we conceive of the organism as a psycho-physical individuality, a mind-body or body-mind, as we will." And Thomson and Geddes, in their manual on "Evolution,' say: "The living organism differs from any machine in its greater efficiency; and especially in this that the transfer of energy into it is attended with effects conducive to further transfer and retardation of dissipation. Again in this that it is a self-stoking, self-repairing, self-preservative, self-adjusting, self-increasing, self-producing engine." And later on they add: "We feel compelled to recognize the persistence of some originative impulse within the organism, which expresses itself in variation and mutation, and in all kinds of creative effort and endeavour."

Another protest against the view that mechanism is the explanation of the organism is that of A. D. Darbishire,* who maintains that "matter is subservient to spirit; that structure is the result of activity and not activity the result of structure." "Those who hold this view do not think," he says, "that the mechanistic explanation is false; they believe that it gives a very true picture of the proximate causes of the mechanical devices made use of by life."

But perhaps the best known advocate of vitalism is the great experimenter, Driesch, who has come to the conclusion that there is in life a great controlling and ordering principle, which he calls "entelechy."† By this he attempts to explain individuality, and development, regulation of the organism, regeneration, &c., &c. It is regarded as constructing the organism as a man constructs a machine, making use of things physical and laws physical.

* Introduction to a Biology." London. 1917.

† See Driesch's Aberdeen Gifford Lectures on "The Science and Philosophy of the Organism."

Among those who have done much to popularise vitalism Samuel Butler deserves special mention. He is best known as the exponent of the "memory" theory of development.* He was not the first to put forward this theory, as Hering, Semon, and others had adopted it, but Butler made an effective appeal to the public. He shows that consciousness and volition have a tendency to vanish when practice has rendered any habit exceedingly familiar; and says if we admit that the mere presence of an elaborate but unconscious performance carries with it a presumption of infinite practice, we shall find it impossible to draw the line at those actions which we see acquired after birth. "The developing chick," he maintains, "works with such absolute certainty [making flesh, bones, feathers, &c.], and so vast an experience that it is utterly incapable of following the operations of its own mind—as accountants have been known to add up long columns of pounds, shillings and pence, running the three fingers of one hand, a finger for each column, up the page, and putting the result down correctly at the bottom, apparently without an effort."

Many others have adopted the theory that development is guided by memory, and among the most important of its advocates is Sir Francis Darwin, whose presidential address to the Botany Section of the British Association (1908) urges its importance. Darwin says: "It seems to me certain that in development we have an actual instance of habit." And he adds: "If this be so, somatic inheritance must be a *vera causa*."

Yet another supporter of neo-vitalism is Bergson, who has done much to interest thinking people in life and heredity. He, like Butler, lays great stress on memory, which he regards as one of the marked characteristics of life. But his great idea is that there is in life a great *impetus*, that flows like a stream from generation to generation, gathering experience as it flows onwards, perpetually adapting itself, constantly creating some-

* See his "Life and Habit," "Unconscious Memory," and other works.

thing new. This view is intended to explain how we carry with us all of our past, and how this past is always liable to crop up in our psychic life. Like the Weismannic view, this of Bergson's recognises that the past remains present to us; but it gives to the living organism an effective power to modify and shape.

In conclusion, I should like to say that it seems to me that we are still far from clear vision in the realm of evolution. We can only as yet get partial views, and much of our argument is by vague simile. But I believe that for practical purposes it is wise still to accept a kind of dualism in the organic world. We seem to have failed completely to make things plain by mechanistic monism, and the ordinary citizen gets lost in the maze of the metaphysical monism advocated by Haldane and others. We can safely say that while there is much in the organism that can be weighed and measured, and is fully and satisfactorily explained as mechanism, there is also much that cannot be so explained, and that may be regarded as outside space, and as distinctive of life.

Such a conclusion does not suggest that the rôle of natural selection is abolished, but rather indicates that natural selection is not "all-sufficient." Instead of playing the part of creator, it may be regarded as active in pruning away the unfit—a far from unimportant task.

And the effect of adopting the definite dualistic view need not be, as not a few have suggested, the end of all scientific inquiry. On the contrary, it may be that this view will add zest to the pursuit of knowledge. Darbishire found it so, as we gather from his description of the effect of his reading Butler's work. "We read 'Life and Habit,'" he says, "in 1909. We had been brought up in the school of Natural Selection; our lectures on Evolution began with Charles Darwin. Evolution as explained by natural selection was a drab thing, in which we had to believe. The change wrought in us by reading 'Life and Habit' was miraculous. An extraordinary change had also come over the living things we saw. They appeared as they had

never appeared before. They wore an uncouth aspect which was unfamiliar and yet strangely familiar to us. They were alive. Evolution from that time became a thing in which it was not a necessity but a joy to believe."

Do we not also realize that the thought of a common vital impulse, such as Bergson suggests, brings with it a wider outlook for man? "An organic being," writes Charles Darwin, "is a microcosm, a little universe formed of a host of self-propagating organisms inconceivably minute and numerous as the stars in heaven." And Samuel Butler adds: "As these myriads of smaller organisms are parts and processes of us, so are we but parts and processes of life at large." And Haldane has the same thought when he says: "The individual organism, like the individual cell in a complex organism, belongs to a wider organic whole, apart from which much of its life is unintelligible."

December 14th, 1920.

T. Edens Osborne in the Chair.

"THE BIRDS OF HILLSBOROUGH."

By Nevin H. Foster, F.L.S., M.R.I.A., M.B.O.U.

The district to which this paper refers may be taken as a circular area, 8 miles in diameter, having the village of Hillsborough as its centre; its circumference just reaching to Larchfield, Legacurry, Lisburn, Lissue, Broomhedge, Spence's Bridge, Shankerburn, Dromore, Lough Aghery and Ballycrune—this area embracing about 32,160 acres. Almost all of it is situated in County Down, but it extends for about a mile on the north into County Antrim. The altitude in its lowest portion at the River Lagan is about 100 feet above sea level, rising to 596 feet in the townland of Clogher, a little over a mile south of the village. For the most part the land is in a high state of cultivation, but it contains one rather large peat moss (Drumlough) and numerous small patches of mossy, moory or marshy ground. Its lakes include Lough Aghery (formerly spelt Achray), Lough Erne, Hillsborough Park Lake, Hillsborough Demesne Lake and McKee's Dam, but in addition to these there are several smaller lakes or ponds. Through its northern part runs the River Lagan and a portion of the Belfast to Lough Neagh Canal, and there are numerous streams. Though no extensive woods occur there are many groves and plantations, and all through the district deciduous and coniferous trees are numerous. The modern practice of cutting down high hedges has no doubt militated against our hedge-frequenting birds, but there still remains ample cover of this class. In a district with such varied topography one would expect the *Ornis* to be comparatively rich, and such we find to be the case.

MUTE SWANS AND CYGNETS, HILLSBOROUGH DEMESNE.

Photo: *G. G. McCready.*

For the purposes of this paper all the available avifaunal records have been consulted and included, but the major part has been compiled from the writer's notes since 1902.

The subjoined list of the Birds of Hillsborough embraces 109 species (exclusive of those cited in square brackets whose status is doubtful), of which 76 have been known to breed in the district. In the course of a series of monthly notes from 1902 till 1918, the following shows the average numbers of bird species actually observed by the writer in each month :—

January,	...	...	45	species.
February,	...	...	45·7	,,
March,	...	...	48·5	,,
April,	...	...	52·9	,,
May,	...	...	58	,,
June,	...	...	55·6	,,
July,	...	...	56	,,
August,	...	...	52·1	,,
September,	...	...	48·8	,,
October,	...	...	47	,,
November,	...	...	46·2	,,
December,	...	...	47·6	,,
The yearly average being			74·69	,,

Needless to state this list cannot be regarded as complete ; for doubtless many casuals may have visited the district unnoted. As an instance of this may be cited the observation of an Oyster-catcher—a bird one would not expect here—and it was a mere matter of luck that the writer in passing Munroe's Dam chanced to see it. However, this paper may be taken as a basis to which future workers in detailed ornithological distribution may add.

The measurements of eggs cited are the greatest length and greatest breadth of the egg and are stated in millimetres. The weights—in grammes—of full eggs are those of fresh eggs, it being recognised that eggs lose some 15% in weight during the process of incubation. Measurements and weights are given only for eggs taken in the district.

ANNOTATED LIST OF THE BIRDS OF HILLSBOROUGH.

The order and nomenclature here adopted is that of the B.O.U. List, 2nd Edition, 1915.

Order PASSERIFORMES.

Family CORVIDÆ.

[**Corvus corax.** *Linné.* RAVEN.

Local tradition asserts that the Raven formerly bred in Hillsborough Park, but no reference to this can be found in any authoritative work. It is possible that this statement should be referable to the following species.]

Corvus cornix *Linné.* HOODED CROW.

Thompson states* that grey crows bred on a wooded islet in Lough Aghery. This may be taken as authentic, but for many years past this bird has not been seen in the district.

Corvus monedula *Linné.* JACKDAW.

Resident and common, usually breeding in disused chimneys, but often in trees, particularly those clothed with ivy. Numbers formerly bred in rabbit holes in Hillsborough Park.† Average size of eggs 34·39 x 25·66 mm. ; average weight of full eggs 11·91 gr., of empty shells ·8 gr.

Corvus frugilegus *Linné.* ROOK.

Resident and common. Several rookeries occur in the district, the largest of which contains annually about 120 nests. Average size of eggs 39·29 x 27 97 mm. ; average weight of full eggs 16·07 gr., of empty shells 1·045 gr.

Pica pica (*Linné*). MAGPIE.

This bird was first observed in Ireland towards the end of the 17th century but is now resident all through the country as obtains in this district. The nest is usually placed in the upper part of a tall tree but the bird also utilises high Whitethorn (*Cratægus Oxyacantha*) hedges. From such a situation a nest now in the Belfast Municipal Museum was obtained. When fresh taken this nest weighed over 70 lbs. Average size of eggs 33·53 x 23·62 mm. ; average weight of full eggs 9·76 gr., of empty shells ·5958 gr.

Garrulus garrulus hibernicus. *Witherby & Hartert.* IRISH JAY.

The Jay can only be regarded as an occasional wanderer to the district. A pair was observed in the Demesne about 1900, and a single bird in the same place in December, 1907.

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* *Nat. Hist. of Ireland*, Vol. II, p. 146.

† *Nat. Hist. of Ireland*, Vol. I, p. 324.

Family STURNIDÆ.

Sturnus vulgaris *Linné.* STARLING.

Resident and numerous, but becoming less so in the Autumn and Winter months. At this season it is probable that many of our Starlings betake themselves to the sea coast, for at this time countless numbers may be seen each evening at sunset coming in to roost on the Technical Institute and Assembly's Buildings, Belfast. Average size of eggs 28·79 x 21·34 mm.; average weight of full eggs 7 gr., of empty shells ·497 gr.

Pastor roseus (*Linné*). ROSE-COLOURED PASTOR.

The only recorded instance of this species in the district is one shot here in July, 1836.*

[A GOLDEN ORIOLE (**Oriolus oriolus** (*Linné*)) was said to have been seen about 2 miles north of the village in September, 1911.]

Family FRINGILLIDÆ.

Chloris chloris (*Linné*). GREENFINCH.

The Greenfinch (locally called Green Linnet) is resident and numerous, packing into large flocks in Autumn. Average size of eggs 20·13 x 13·88 mm.; average weight of full eggs 1·94 gr., of empty shells ·1019 gr.

Coccothraustes coccothraustes (*Linné*). HAWFINCH.

Thompson states† that a very fine specimen was shot near Hillsborough about the year 1829. One said to have been shot in Park about 1899. Rev. Allan Ellison, when here on a visit in July, 1905, thought he detected a pair flying overhead.

Carduelis carduelis britannica (*Hartert*). GOLDFINCH.

Formerly common, this bird has now become very rare. In 1901 Mr. R. J. Pack Beresford released 24 birds obtained from Co. Carlow, but this did not seem to have any appreciable effect on the population. In May, 1905, a nest of this species was found in a high beech hedge, from which the young were duly reared.

Spinus spinus (*Linné*). SISKIN.

Resident in the district in small numbers, but the local population is augmented in Winter by flocks of migratory birds. The nests, so far as discovered, are always placed far out on a branch of Douglas Spruce and at a high elevation.

Passer domesticus (*Linné*). HOUSE-SPARROW.

Resident and abundant. As obtains elsewhere, the nests are of two kinds (*a*) a domed structure among the finer branches of the upper part of a tree, or (*b*) a cup-shaped nest in a hole in a tree or building or in the thatch of houses. Average size of eggs 21·22 x 15·02 mm.; average weight of full eggs 2·635 gr., of empty shells ·1712 gr.

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* *Nat. Hist. of Ireland*, Vol. I, p. 296.

† *Nat. Hist. of Ireland*, Vol. I, p. 259.

Fringilla cœlebs *Linné.* CHAFFINCH.

Resident and probably the most abundant of our small birds, whose song may be heard from the middle of February till about the end of June. A specimen almost pure white in colour was shot a short distance from the village a few years ago. Average size of eggs 18·98 x 14·12 mm.; average weight of full eggs 2·024 gr., of empty shells ·1211 gr.

Fringilla montifringilla *Linné.* BRAMBLING.

An irregular Winter visitant—a few probably visiting the district nearly each year, when they may be found consorting with Chaffinches generally in the neighbourhood of beech trees.

Acanthis cannabina (*Linné*). LINNET.

A not numerous resident. Average size of eggs 18·23 x 13·49 mm.; average weight of full eggs 1·667 gr., of empty shells ·08 gr.

Acanthis linaria cabaret (*P. L. S. Müller*). LESSER REDPOLL.

Resident in considerable numbers. A seasonal movement is observable, most of these birds deserting the higher parts of the district in Autumn and spending the Winter in the lower lying portions. Average size of eggs 16·16 x 12·22 mm.; average weight of full eggs 1·289 gr., of empty shells ·0643 gr.

Acanthis flavirostris (*Linné*). TWITE.

Resident in small numbers but usually keeping to the higher lying portions of the district, *i.e.*, Drumlough Moss, where it breeds among the ling (*Calluna vulgaris*). Average size of eggs 17·1 x 13·24 mm.; average weight of full eggs 1·396 gr., of empty shells ·0833 gr.

Pyrrhula pyrrhula pileata *MacGillivray.* BRITISH BULLFINCH.

A not uncommon resident, doing a considerable amount of damage to the buds of fruit trees in Spring but later destroying seeds of noxious weeds. Average size of eggs 18·66 x 13·55 mm.; average weight of full eggs 1·813 gr., of empty shells ·118 gr.

Loxia curvirostra *Linné.* CROSSBILL.

Thompson records* this bird from Hillsborough Park in January and February, 1838. It is probable that Crossbills bred here in 1901 as a small party was observed for several months in the early Summer frequenting a plantation of Douglas Spruces in the Park. A flock of about a dozen was seen feeding on the seeds of the Douglas Spruce in July, 1909, and Crossbills were noted several times in the succeeding Autumn and Winter. It appears to be here as elsewhere in Ireland a somewhat erratic visitant.

[On the evening of 12th June, 1920, and on the following morning a bird was observed feeding among potatoes, &c., in some of the gardens at the south end of the village. The writer had only a momentary vision of it, but others saw it for longer or shorter periods. The bird appears to have been the DOMINICAN CARDINAL, **Paroaria larvata** *Boddaert*, a native of Brazil, which is imported in considerable numbers to this country and kept in confinement, from which undoubtedly this bird had escaped. It is the "Pope" of dealers.]

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* *Nat. Hist. of Ireland*, Vol. I, p. 278.

Emberiza calandra *Linné.* Corn-Bunting.

Resident in small numbers and very locally distributed in the neighbourhood. Average size of eggs 22·72 x 16·54 mm. ; average weight of full eggs 3·175 gr., of empty shells ·194 gr.

Emberiza citrinella *Linné.* Yellow Hammer.

Resident and common. Average size of eggs 20·34 x 15·78 mm. ; average weight of full eggs 2·702 gr., of empty shells ·1581 gr.

Emberiza schœniclus *Linné.* Reed-Bunting.

Resident and common. Forsaking its Summer habitat—marshes and rushy meadows—it frequents stubble and potato fields in Winter, and may frequently be seen following the plough. The Cuckoo frequently utilises the nest of this species for the depositing of its egg. Average size of eggs 19·14 x 14·28 mm. ; average weight of full eggs 2·102 gr., of empty shells ·1211 gr.

Family ALAUDIDÆ.

Alauda arvensis *Linné.* Sky-Lark.

Resident and common, particularly in the lower-lying portions of the district. The song may be heard as early as January, and in the early season it is frequently uttered whilst the bird is on the ground. In 1920 many were heard singing on the afternoon of 10th October. Average size of eggs 24·5 x 17·07 mm. ; average weight of full eggs 3·618 gr., of empty shells ·22 gr.

Family MOTACILLIDÆ.

Motacilla lugubris *Temminck.* Pied Wagtail.

This bird is said to be less numerous in the district than obtained formerly. During the Winter months one can scarce fail to see one or a pair in the village street, but by March they change their habitat. A Cuckoo's egg has more than once been found here in the nest of this species. Average size of eggs 18·99 x 14·86 mm, ; average weight of full eggs 2 gr., of empty shells ·1286 gr.

Motacilla cinerea *Tunstall.* Grey Wagtail.

A few pairs are resident in the district, being principally seen by the side of streams or lakes. The nest, however, is by no means always near the water edge, but is frequently placed in holes in walls or buildings at a considerable distance from water. Average size of eggs 19·44 x 13·8 mm. ; average weight of full eggs 1·912 gr., of empty shells ·105 gr.

Anthus pratensis (*Linné*). Meadow-Pipit.

Resident and common. This bird is most frequently victimised by the Cuckoo, as appears to be the case all through Ireland. Average size of eggs 19·51 x 14·48 mm. ; average weight of full eggs 2·157 gr., of empty shells .125 gr.

Family CERTHIDÆ.

Certhia familiaris britannica *Ridgway.* BRITISH TREE-CREEPER.

Resident in small numbers. Average size of eggs 16 x 12·06 mm.; average weight of full eggs 1·177 gr., of empty shells ·0633 gr.

Family REGULIDÆ.

Regulus regulus (*Linné*). GOLDCREST.

This species—smallest of European birds—is resident and common. The severe winter of 1916-17 practically exterminated it in the district, but it is again becoming very numerous. The nest is usually attached to and hanging from the under side of a Douglas Spruce branch but has been observed far out on the top of a Yew branch and once on the top of a Spruce branch close to the trunk. Average size of eggs 13·61 x 10·21 mm.; average weight of full eggs ·74 gr., of empty shells ·0357 gr.

Family PARIDÆ.

Parus major newtoni *Prázák.* BRITISH GREAT TITMOUSE.

Resident and common. Average size of eggs 18·22 x 13·78 mm.; average weight of full eggs 1·843 gr., of empty shells ·102 gr.

Parus ater britannicus *Sharpe & Dresser.* BRITISH COAL-TITMOUSE.

Resident and common. All the specimens obtained in the district proved of this sub-species, and although closely looked for *P. a. hibernicus* has not been observed here. Average size of eggs 17·86 x 12·33 mm.; average weight of full eggs 1·415 gr., of empty shells ·0633 gr.

Parus cæruleus obscurus *Prazák.* BRITISH BLUE TITMOUSE.

Resident and by far the most numerous species of the Titmouse family in the district. Average size of eggs 15·2 x 11·52 mm.; average weight of full eggs 1·06 gr., of empty shells ·0633 gr.

Ægithalus caudatus roseus (*Blyth*). BRITISH LONG-TAILED TITMOUSE.

Up till the severe Winter of 1916-17 this bird was resident and not uncommon, but its presence since then has not been detected in the district until November, 1920, when Mr. Horsbrugh saw two of these birds in his garden. Although this bird generally builds its nest in a shrub or bush within ten feet of the ground, a nest has been noted in the fork of a slender branch at an elevation of about 60 feet.

Family LANIDÆ.

Lanius excubitor *Linné.* GREAT GREY SHRIKE.

Ussher records* a male of this species shot near Lisburn, in Co. Down, 27th December, 1886, which is the only note for this district of a bird of the Shrike family.

**Birds of Ireland*, p. 44.

Family AMPELIDÆ.

Ampelis garrulus (*Linné*). WAXWING.

An irregular Winter visitant. One shot in Lissue, Co. Antrim, and another seen in Hillsborough Demesne in December, 1903 ; one shot near St. John's Church, 3rd February, 1917, are all that have been observed in the district.

Family SYLVIIDÆ.

Sylvia communis *Latham.* WHITETHROAT.

A regular Spring migrant usually appearing about the first of May (earliest 24th April. in 1902). The presence of the male is soon detected by his almost continuous singing, which ceases early in July ; but on the morning of 6th August, 1909, one was heard in full song. Average size of eggs 18·8 x 13·82 mm. ; average weight of full eggs 1·886 gr., of empty shells ·102 gr.

Locustella nævia (*Boddaert*). GRASSHOPPER-WARBLER.

A Spring migrant whose visits to the district appear to be somewhat irregular ; in some years plentiful, whilst in others it is not seen or heard. Average size of eggs 18·03 x 13·97 mm. ; average weight of full eggs 1·782 gr., of empty shells ·1 gr.

Acrocephalus schœnobænus orientalis (*Linné*). SEDGE-WARBLER.

This species usually arrives about 1st May, and is always numerous. The late John Cottney maintained that the male never sang in the proximity of the nest. Average size of eggs 17·13 x 12·75 mm. ; average weight of full eggs 1·501 gr., of empty shells ·075 gr.

Phylloscopus trochilus (*Linné*). WILLOW-WARBLER.

Probably the most numerous of the warblers, this bird usually arrives about the middle of April (earliest 3rd April, in 1906 , and from this time till the middle of July one can scarce go about without hearing its melodious if somewhat plaintive song. Occasionally the song is resumed, but much more faintly, in the Autumn. Average size of eggs 15·09 x 12·11 mm. ; average weight of full eggs 1·162 gr., of empty shells ·059 gr.

Phyllosocopus collybita (*Vieillot*). CHIFFCHAFF.

The earliest of the regular Spring migrants to arrive in the district, generally appearing in the last week of March (earliest 23rd, in 1918). Like the preceding species the song ceases about mid July, but is resumed in August and uttered occasionaliy during September. Average size of eggs 14·53 x 11·58 mm. ; average weight of full eggs 1·021 gr., of empty shells ·07 gr.

Family TURDIDÆ.

Turdus viscivorus *Linné.* MISSEL-THRUSH.

The Missel-Thrush or Mistle-Thrush was first noticed in Ireland about 1808, but is now widely distributed and common. Here it is known as the "Jay" or "Jay-Thrush." It is said to be an early nester, but in this district it does not appear to be specially so. Average size of eggs 30·33 x 21·49 mm. ; average weight of full eggs 7·63 gr., of empty shells ·4566 gr.

Turdus musicus clarkii (*Hartert*). British Song-Thrush.

The song of this bird may be heard in every month of the year, with the possible exception of August. Its nest has been seen early in March. As a rule this thrush lines its nest with a waterproof coating composed of rotten wood, dung, &c., but one found in 1911 had only a very flimsy plastering of such substance inside which was a profuse lining of dead leaves. As the three eggs in this nest were below normal size—they averaged 25·82 x 20·32 mm.—it is probable it was the first attempt of a young bird. This nest and eggs passed into the collection of the late H. L. Orr. Average size of eggs 27·28 x 20·45 mm. ; average weight of full eggs 6·004 gr., of empty shells ·3615 gr.

Turdus iliacus (*non Linné*). Redwing.

Fairly large flocks frequent the district every Winter. Their arrival is usually about the end of October, but an exceptionally early date is the 26th of August in 1819 when six of these birds were observed. On their arrival they appear to devote their attention to Yew berries (which are plentiful in the Demesne) till they are consumed, afterwards spreading themselves over the fields and frequently consorting with Starlings. They are seldom seen after the beginning of April.

Turdus pilaris *Linné*. Fieldfare.

Formerly known as a numerous Winter visitant but for the past 5 or 6 years it has become very scarce. It usually arrived from the middle to end of October and remained later than the Redwing, the latest noted date being 10th May in 1910.

Turdus merula *Linné*. Blackbird.

By far the most numerous of the Thrush family in the neighbourhood. Partial albinos of this species are not uncommon. Average size of eggs 29·54 x 21·2 mm. ; average weight of full eggs 7·024 gr., of empty shells ·44 gr.

Erithacus rubecula melophilus *Hartert*. British Redbreast.

Resident and very common. Like the Song-Thrush its song may be heard throughout the year except in August. Average size of eggs 19·56 x 14·48 mm. ; average weight of full eggs 2·296 gr., of empty shells ·15 gr.

Saxicola rubicola (*Linné*). Stonechat.

This species is resident in small numbers but is very local in its habitats, being usually confined to the neighbourhoods of Drumlough Moss, Maze and Canal banks. Like the Goldcrest and Long-tailed Tits its numbers appeared to have been much reduced by the severe Winter of 1916-17. Average size of eggs 18·73 x 14·2 mm. ; average weight of full eggs 1·989 gr., of empty shells ·105 gr.

Saxicola rubetra (*Linné*). Whinchat.

A Summer visitant and one of our rarest migrants. The only observations of this bird in the district being in July, 1907, and September, 1908, both in a meadow adjacent to the Maze racecourse.

Œnanthe œnanthe (*Linné*). Wheatear.

Can only be regarded as an occasional Summer visitant. Has been observed at Maze and in Hillsborough Park, generally in the early part of its season in this country.

Family ACCENTORIDÆ.

Accentor modularis (*Linné*). Hedge-Sparrow.

Resident and very common. Average size of eggs 19·86 x 14·25 mm.; average weight of full eggs 2·096 gr., of empty shells ·133 gr.

Family CINCLIDÆ.

Cinclus cinclus hibernicus *Hartert.* Irish Dipper.

For a number of years a pair constantly frequented the stream ("Conn's River") in and below Hillsborough Demesne, where they regularly nested. Since 1909 they seem to have deserted the place. Average size of eggs 22·62 x 16·37 mm.; average weight of full eggs 4·007 gr., of empty shells ·24 gr.

Family TROGLODYTIDÆ.

Troglodytes troglodytes (*Linné*). Wren.

Resident and very common. Locally known as "Chitty Wren" or "Chit." Average size of eggs 16·72 x 12·31 mm.; average weight of full eggs 1.361 gr., of empty shells ·075 gr.

Family MUSICAPIDÆ.

Musicapa grisola *Linné.* Spotted Flycatcher.

This migratory species does not usually arrive till about mid May, but has been observed as early as 2nd May in 1912 and 1916. Average size of eggs 19·13 x 14·11 mm.; average weight of full eggs 2·02 gr., of empty shells ·1 gr.

Family HIRUNDINIDÆ.

Hirundo rustica *Linné.* Swallow.

Apparently now not so plentiful as obtained some years ago, yet considerable numbers arrive yearly about mid April. The earliest record for the district is 1st April, in 1918, and the latest 22nd November, in 1907. Average size of eggs 19·3 x 13·69 mm.; average weight of full eggs 1·912 gr., of empty shells ·104 gr.

Delichon urbica (*Linné*). Martin.

Up till the early nineties a small colony of Martins (often spoken of as "House-Martins") yearly arrived and bred in Hillsborough Village, but afterwards deserted the place. In 1903, however, a few appeared, and since they have resorted to us in increasing numbers. They usually arrive about 1st May, but an exceptionally early appearance was noted in 1906, on 12th April. Their departure usually takes place about mid September, but they have been observed feeding their young in the nest in the last week of this month, and the latest observation was on 3rd October in

1907. Perhaps the cause of this disappearance from about 1893 till 1903 was the destruction of their nests by citizens, who objected to having their walls disfigured. That such a practice did not obtain of old is recorded by Thompson, who says* he observed that in Hillsborough, as in Antrim, the inhabitants were unwilling to disturb their friends, and for the sake of uniformity whitewashed the Martins' domiciles when performing this annual process in their own houses. Average size of eggs 19·24 x 13·91 mm. ; average weight of full eggs 1·993 gr., of empty shells ·1066 gr.

Riparia riparia (*Linné*). SAND-MARTIN.

An annual visitant in large numbers and breeding in banks of sand-pits at Maze. Average size of eggs 17·02 x 12·24 mm. ; average weight of full eggs 1·38 gr., of empty shells ·078 gr.

Order COCCYGES.

Family CUCULIDÆ.

Cuculus canorus *Linné*. CUCKOO.

The latter half of April is usually the time of the Cuckoo's arrival in the district, the earliest note being 11th April. This bird's parasitic habits are well known and here its victim is generally the Meadow-Pipit, but its egg has also been seen in the nest of Redbreast, Hedge-Sparrow, Pied Wagtail and Reed-Bunting. Average size of eggs 22·44 x 16·42 mm. ; average weight of full eggs 3·294 gr., of empty shells ·1728 gr.

Order CORACIIFORMES.

Family CYPSELIDÆ.

Micropus apus *Hartert*. SWIFT.

The most regular migrant in its times of arrival and departure, the former occuring on or near the 1st of May (earliest date 20th April in 1909). By the middle of August the bulk of the Swifts depart but a few may be seen for a week or so afterwards. The latest recorded date by Thompson† is 11th September in 1836, but in 1918 the writer saw one on 15th September. The latest recorded occurrence in Ireland‡ is at Glenarm, Co. Antrim, on 8th October, 1903. It may be emphasised that the Swift is a bird of little affinity with the Swallow, in fact belonging to a far-removed ORDER of birds. Its nearest relations are the Humming Birds of America. Average size of eggs 24·67 x 16·13 mm. ; average weight of full eggs 3 gr., of empty shells ·23 gr.

[An observant farmer informed me that on one occasion a bird had quickly flown past him at close quarters. The bird, he said, was just like a Swift but much larger and with its upper parts the colour of a Sand-Martin. Possibly this bird may have been an ALPINE SWIFT, **Micropus melba** *Hartert*. This bird has been recorded four times from Ireland, the last of which was a dead bird found near Lough Neagh in May, 1866.]

* *Nat. Hist. of Ireland*, Vol. I, p. 394.

† *Nat. Hist. of Ireland*, Vol. I, p. 417.

‡ *Irish Naturalist*, Vol. XII, p. 320.

Family CAPRIMULGIDÆ.

Caprimulgus europæus *Linné.* NIGHTJAR.

Though the Nightjar is known to nest on the Antrim Hills a few miles north of the district, and on Slieve Croob, some 5 miles to the south, the only record of its occurrence here is that given by Thompson* of one shot in Hillsborough Park on 25th September, 1835.

Family ALCEDINIDÆ.

Alcedo ispida *Linné.* KINGFISHER.

Several pairs of these birds reside and breed with us. Average size of eggs 22·5 x 17·78 mm. ; average weight 3·554 gr., of empty shells ·2166 gr.

Order STRIGIFORMES.

Family FLAMMEIDÆ.

Flammea flammea (*Linné*). BARN-OWL.

A not uncommon resident, but owing to its nocturnal habits seldom observed. "Pellets" from its nesting place in a pigeon loft in Hillsborough Park yielded bones, principally Rats and Mice, but also of one young Rabbit and one bird—a Greenfinch. Surely one of our most useful birds!

Family STRIGIDÆ.

Asio otus (*Linné*). LONG-EARED OWL.

Like the preceding species this bird is seldom observed, but is not an uncommon resident, nesting in Fir trees.

[The Short-eared Owl (**Asio accipitrinus** *Pallas*) doubtless occurs in Winter, but no definite information as to this is forthcoming.]

Otus scops (*Linné*). SCOPS OWL.

A bird of this species was shot at Hillsborough about March, 1853. It is preserved in the Dublin Museum.†

Order ACCIPITRIFORMES.

Family FALCONIDÆ.

Buteo buteo (*Linné*). BUZZARD.

Formerly resident in the district, this bird has long since ceased to be a member of our local Avifauna. Thompson states‡ that several specimens from Hillsborough Park had come under his observation ; and Knox § says that this bird bred in trees in Hillsborough Park.

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* *Nat. Hist. of Ireland*, Vol. I, p. 421.

†Ussher's *Birds of Ireland*, p. 119.

‡ *Nat. Hist. of Ireland*, Vol. I. p. 75.

§ *Hist. of Co. Down*, p. 647. (1875).

Buteo lagopus (*J. F. Gmelin*). ROUGH-LEGGED BUZZARD.

A female of this species, the 13th obtained in Ireland, was shot about a couple of miles from Hillsborough in October, 1903. This specimen was in existence until recently, but unfortunately seccumbed to the ravage of moths.

Accipiter nisus (*Linné*). SPARROW-HAWK.

A common resident, nesting in trees and, unlike the Kestrel, constructing its own nest. Average size of eggs 39·37 x 32·52 mm. ; average weight of full eggs 23·409 gr., of empty shells 1·821 gr.

Falco tinnunculus *Linne.* KESTREL.

Probably the commonest of our "Birds of Prey" resident and nesting in the district. Average size of eggs 39·37 x 31·23 mm. ; average weight of full eggs 21·148 gr., of empty shells 1·6 gr.

Order PELECANIFORMES.

Family PHALACROCORACIDÆ.

Phalacrocorax carbo (*Linné*). CORMORANT.

Annually from November till March a bird, sometimes 3 or 4, of this species may be seen perched on a tree in the island in Hillsborough Park Lake or fishing in the water. These birds generally wear the white breast feathers of immaturity.

Order ANSERIFORMES.

Family ANATIDÆ.

Wild Goose. *sp. inc.* Gaggles have frequently been seen flying overhead, too high for identification.

Branta canadensis *Salvadori.* CANADA GOOSE.

In the early nineties a pair of these birds came to Hillsborough Park where they have been comparatively little disturbed and have increased in numbers and regularly nest. Average size of eggs 88·26 x 60·73 mm. ; average weight of full eggs 163·164 gr., of empty shells 17·32 gr.

Alopochen ægyptiacus (*Linne*). EGYPTIAN GOOSE.

Thompson states* that one was shot near Moira in the middle of January, 1833, and in the succeeding page he says that formerly these birds were kept in numbers in the lakes in Hillsborough Park. There were still a few there about the year 1889 but they have since disappeared.

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* *Nat. Hist. of Ireland*, Vol. III, p. 64.

Female Wild Duck on Nest, Hillsborough Demesne.

Photo: *G. G. McCready.*

Cygnus cygnus (*Linné*). WHOOPER SWAN.

Thompson states* that Wild Swans have occurred at Lough Aghery and Hillsborough Park but as at that time the difference between the Whooper and Bewick's Swan does not appear to have been appreciated it is doubtful to which species these records should be relegated. However on 1st December, 1912, five birds were noted on Hillsborough Park Lake which were undoubtedly Whooper Swans.

Cygnus bewicki *Yarrell.* BEWICK'S SWAN.

In December, 1919, a mature female with two immature birds of this species came to McKee's Dam. The mature bird was shot a few days afterwards, but the two cygnets remained for about a fortnight, when they took their departure.

Cygnus olor (*Gmelin*). MUTE SWAN.

Scarce a lake or pond in the district does not provide habitat and breeding place for a pair of these birds in a truly feral condition. On Lough Aghery, which is a mile in length, 2 or 3 pairs nest, but on this lake in Winter it is not unusual to observe as many as 100 of these birds. Average size of eggs 107·62 x 73-36 mm. ; average weight of full eggs 315.636 gr., of empty shells 38·943 gr.

Anas boschas *Linné.* WILD DUCK OR MALLARD.

The Mallard is resident and nests in the district in fair numbers. In Winter large flocks of immigrant birds swell the local population. Thompson records† a nest of this species in Hillsborough Park, formed in the old nest of a Magpie about 40 feet from the ground in a Silver Fir tree. This nest contained 15 eggs, and he was of opinion that the young birds had been successfully brought out. Average size of eggs 56·82 x 41·33 mm. ; average weight of full eggs 50·273 gr., of empty shells 4·783 gr.

Querquedula crecca (*Linné*). COMMON TEAL.

Resident and breeding in small numbers.

Mareca penelope (*Linné*). WIGEON.

From 1905 till 1909 numbers of this species frequented the lakes in the Park and Demesne throughout the Winter, but before and since this period they have not been observed. A male in fine plumage was seen on "The Cuts" by the side of the railway a little over a mile from Hillsborough on 21st May, 1906.

Dafila acuta (*Linne*). PINTAIL.

A female of this species was observed on the lake in the Demesne on 1st February, 1909, but on the following day it had disappeared.

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* *Nat. Hist. of Ireland,* Vol. III, pp. 9 and 20.

† *Nat. Hist. of Ireland,* Vol. III, p. 76.

Nyroca ferina (*Linné*). Pochard.

A few of these birds spend the Winter on the lakes in the district.

Nyroca fuligula (*Linné*). Tufted Duck.

Frequents the lakes annually in Winter in larger numbers than the preceeding species.

Glaucion clangula (*Linné*). Golden-eye.

All through the month of June, 1916, a female or inmature bird of this species (probably a cripple) frequented the lake in the Demesne. During December, 1918, and January, 1919, a pair were seen on the lake in the Park.

Order ARDEIFORMES.

Family ARDEIDÆ.

Ardea cinerea *Linné*. Heron.

This bird which formerly bred in the district has now apparently ceased to do so. It is common, however, except perhaps in the nesting season. Thompson states[1] that the heronry in Hillsborough Park contained about 50 nests and it still nested these up to about 1900. The same author tells us[2] on the authority of Rev. J. Dubourdieu that up till about 1803 Herons nested on the ground in an island in Lough Aghery. It may be stated that the usual nesting site of this species is high up on tall trees. Its local name is "Heron-Cran" or "Cran." A nest seen in May, 1920, on a tree in one of the islands in Lough Aghery from which evidently young had been hatched is doubtless referable to this species.

Order CHARADRIIFORMES.

Family CHARADRIIDÆ.

Scolopax rusticola *Linné*. Woodcock.

The Woodcock has been known to breed in Hillsborough Park since 1844 and still nests there in considerable numbers. In Winter many immigrant birds inhabit the district. Size of eggs 43·51 x 33·49 mm. ; average weight of full eggs 25·157 gr., of empty shells 1·4 gr.

Gallinago gallinago (*Linne*). Common Snipe.

A common breeding species, nesting as a rule in comparatively dry situations, *i.e.*, in rushy meadows or bracken-clad uplands. Average size of eggs 39·81 x 27·69 mm. ; average weight of full eggs 14·477 gr., of empty shells ·8357 gr.

Limnocryptes gallinula (*Linne*). Jack Snipe.

A regular Winter visitant, as obtains elsewhere in the British Islands.

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[1] *Nat. Hist. of Ireland*, Vol. II, p. 141. [2] *Ibid*, p. 146.

WOODCOCK ON NEST, HILLSBOROUGH PARK.

Photo: *G. G. McCready.*

Totanus totanus (*Linné*). REDSHANK.

The Redshank nests in small numbers in meadows adjacent to Lough Aghery, and occurs in the lower-lying northern portion of the district occasionally in Winter. Average size of eggs 46·41 x 31·75 mm.; average weight of full eggs 22·612 gr., of empty shells 1·23 gr.

Totanus hypoleucus (*Linné*). COMMON SANDPIPER.

A regular Spring migrant, arriving about the 1st of May, and nesting in small numbers. Average size of eggs 37·85 x 26·67 mm.; average weight of full eggs 13·258 gr., of empty shells ·58 gr.

Numenius arquata (*Linné*). CURLEW.

The Curlew's whistle as it flies overhead has been here noted in every month of the year except January. It is also not uncommonly seen feeding in the fields.

Charadrius apricarius *Linné*. GOLDEN PLOVER.

A regular Winter visitant in small numbers, usually consorting with flocks of Lapwings.

Vanellus vanellus (*Linné*). LAPWING.

The Lapwing, Peewit or Green Plover, is a resident and numerous species breeding both in the higher southern and lower-lying northern parts of the district, but in Winter for the most part forsaking the former regions. Average size of eggs 47·19 x 32·97 mm.; average weight of full eggs 25·819 gr., of empty shells 1·478 gr.

Hæmatopus ostralegus *Linné*. OYSTER-CATCHER.

An unexpected incident was the sight of an Oyster-catcher at Munroe's Dam on 26th June, 1919, where also a few days previously a Redshank had been observed. This bird nests at Lough Neagh, and it may well be that the one seen was on passage from thence to the sea coast.

Order LARIFORMES.

Family LARIDÆ.

Larus canus *Linné*. COMMON GULL.

A regular Winter visitant (October till May), feeding in the fields and often following the plough, but has also been observed in July and August.

Larus argentatus *Pontoppidan*. HERRING-GULL.

The Herring-Gull has been seen in every month of the year but is much more numerous in Winter. The majority of the birds frequenting the district are in immature plumage.

Larus fuscus affinis *Reinhardt*. BRITISH LESSER BLACK-BACKED GULL.

A single bird of this species seen in 1903 constitutes the only record for the district. This is somewhat strange as this bird may constantly be observed at Lough Neagh only some 10 miles distant.

Larus ridibundus *Linné.* Black-headed Gull.

The Black-headed Gull may be seen in the district the year round and in Winter in large numbers. Thompson states* that about the year 1803 a number of these birds took possession of an islet in Lough Aghery as a breeding place and drove out the Herons and nested for several years afterwards to the number of many hundreds, their nests almost covering the whole islet. This apparently continued till about 1832 when they were in their turn evicted, it is said, by the persecution of Hooded Crows. In July, 1905, the Rev. Allan Ellison and the writer found on the Willow trees overhanging the water of Hillsborough Park Lake about 20 nests built of sticks and placed on the branches usually about a foot above the surface but some almost touching the water, which they believed belonged to this species. Certainly at the time there were about 100 Black-headed Gulls about the lake, the majority of which were birds of the year. The gamekeeper informed us that two pairs had nested there the previous year. Since then they have not bred there.

Sterna hirundo *Linné.* Common Tern.

A pair, sometimes three, of these birds usually frequent Hillsborough Park from May till July, and may occasionally be seen at this season on some of the ponds in the district. These do not appear to be breeding birds as no nest could be found, nor were any immature birds ever seen.

Order PROCELLARIIFORMES.

Family THALASSIDROMIDÆ.

Thalassidroma pelagica (*Linné*). Storm-Petrel.

Thompson records† that after a hurricane on 7th January, 1839, two of these birds were found dead near the Castle, Lisburn.

Oceanodroma leucorrhoa *Salvin.* Leach's Petrel.

For the inclusion of this species we are indebted to Thompson, who states‡ that in the Winter of 1831 a specimen was found dead—but in excellent condition and plumage—near Lisburn.

[It may here be stated that the second example found in Ireland of the American Wilson's Petrel, **Oceanites oceanicus** (*Kuhl*), was taken alive after the great storm of September, 1891, near Dunmurry, only a little more than two miles outside our district.]

Order PODICIPIDIFORMES.

Family PODICIPIDÆ.

Podiceps cristatus (*Linné*). Great Crested Grebe.

To the district we can only regard this bird as a Summer visitant, though Thompson says§ that a pair of them remained on the lake in Hills-

* *Nat. Hist. of Ireland,* Vol. II, p. 146.
† *Nat. Hist. of Ireland,* Vol. III, p. 423.
‡ *Nat. Hist.* of *Ireland,* Vol. III, p. 415.
§ *Nat. Hist. of Ireland,* Vol. III, p. 175.

borough Park during the Winter of 1847-48. Usually arriving in March, it has been known to nest on Hillsborough Park Lake, Lough Aghery and McKee's Dam. It appears probable that in some years it does not visit the district. Average size of eggs 51·33 x 34·5 mm. ; average weight of full eggs 32·14 gr., of empty shells 3·375 gr.

Podiceps fluviatilis *Tunstall.* LITTLE GREBE.

A common resident, only leaving the district when severe frosts cover its haunts with ice. It is locally known as the "Diver." Average size of eggs 38·58 x 25·78 mm. ; average weight of full eggs 13·063 gr., of empty shells 1·1917 gr.

Order RALLIFORMES.

Family RALLIDÆ.

Rallus aquaticus *Linné.* WATER-RAIL.

A resident in considerable numbers, though seldom observed owing to its skulking habits. The nest of this species is well concealed and is almost invariably placed among wet surroundings. In December, 1908, and again in February and November, 1909, the unusual sight was witnessed of one of these birds perching in a Willow tree growing at the margin of the lake in Hillsborough Park. Average size of eggs 35·28 x 25·93 mm. ; average weight of full eggs 12·403 gr., of empty shells ·9122 gr.

Crex Crex (*Linné*). CORN-CRAKE OR LAND-RAIL.

A common Spring migrant arriving about the middle of April (earliest 14th April, in 1918). A specimen of this species was shot near Hillsborough on 20th February, 1905, and is in the writer's possession. Average size of eggs 36·86 x 26·47 mm. ; average weight of full eggs 13·539 gr., of empty shells ·834 gr.

Gallinula chloropus (*Linne*). MOOR-HEN.

Resident and very common. Locally known by the more appropriate name of "Water-Hen." Although its usual nesting place is on the ground, or in vegetation growiug in or extending over and close to the water, its nest has more than once been seen here in a high hedge or in an Alder tree at an elevation of about 15 feet. Average size of eggs 44·04 x 31·22 mm. ; average weight of full eggs 23·085 gr., of empty shells 1·9447 gr.

Fulica atra *Linné.* COOT.

Usually called "Bald Coot" this bird is resident and common. Average size of eggs 51·94 x 36·04 mm. ; average weight of full eggs 35·875 gr., of empty shells 3·4 gr.

Order COLUMBIFORMES.

Family COLUMBIDÆ.

Columba œnas *Linné.* Stock-Dove.

Resident in small numbers. Average size of eggs 36 x 28·6 mm.; average weight of full eggs 17·142 gr., of empty shells 1·25 gr.

Columba palumbus *Linné.* Ring-Dove or Wood-Pigeon.

Resident and common. In some Winters large flocks of immigrant birds frequent the district. Average size of eggs 39·78 x 28·65 mm.; average weight of full eggs 18·13 gr., of empty shells 1·261 gr.

Streptopelia turtur (*Linné*). Turtle-Dove.

A specimen (in the writer's possession) was shot about 2 miles from Hillsborough on 24th May, 1904. On dissection it proved to be a female with eggs in the ovary.

Order GALLIFORMES.

Family PHASIANIDÆ.

Phasianus colchicus *Linné.* Pheasant.

The Pheasant is listed as *P. colchicus*, though since the introduction of the Chinese Ring-necked, *P. torquatus*, into the British Islands, about a century ago, these species have been bred together, and being perfectly fertile *inter se*, it is evident that the present race is mongrel. It may be stated that there is no mention of the Pheasant in Ireland before 1589.

In pre-war times large numbers of Pheasants were artifically hatched in Hillsborough Park, but numbers bred naturally in the Park and in the adjoining fields. Not infrequently a blue egg may be found in a nest of normally-coloured eggs. Average size of egg, 43·74 x 36·17 mm.; average weight of full eggs 31·095 gr., of empty shells 3·05 gr.

[For many years a few Golden Pheasants, *Thaumalea pieta*, existed in a semi-feral condition in Hillsborough Park. Since about 1910 they have disappeared, but at present there are in aviaries in the district examples of this species, and also of the following :—Lady Amherst's *T. amherstiæ ; P. versicolor ;* Elliott's *Phasianus elliotti* ; Reeve's *P. reevesii* ; Silver *Euplocomus nycthemerus* ; Swinhoe's *E. swinhoii* ; Mantchurian Eared, *Crossoptilon mantchurinum* ; and Impyean or Monal, *Lopophorus impeyanus* ; some of which have bred in captivity here. It is hardly probable that any of these birds may escape and become acclimatised natives of the country. Should such occur the future historian may have the opportunity of including their names in the local avifauna.]

Perdix perdix (*Linné*). Partridge.

Formerly not uncommon, it is probable the Partridge does not now inhabit the district. The last known nest was in 1904.

Coturnix coturnix (*Linne*). Quail.

Resident and common up till about 1870 the Quail or "Wet-my-foot" can now only be regarded as an irregular Summer visitant. For several years its presence had not been detected, but in 1896 its distinctive call was heard. In 1904 it appeared in considerable numbers, and since it has occasionally visited us. Average size of eggs 31·71 x 23·84 mm.; average weight of empty egg-shells ·8286 gr.

BELFAST

NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.

PROCEEDINGS,

100TH SESSION 1920-1921.

No. 2.

19TH AND 26TH NOVEMBER, 3RD AND 10TH DECEMBER, 1920;
4TH FEBRUARY, 1921;
14TH AND 28TH JANUARY, 11TH AND 25TH FEBRUARY, 1921.

A COURSE OF FOUR LECTURES ON

THE GROUNDWORK OF THE UNIVERSE FROM A CHEMICAL STANDPOINT.

BY PROFESSOR A. W. STEWART, D.Sc.

THE PERCEPTION OF THE INVISIBLE.

BY R. T. BEATTY, M.A., D.Sc.

A COURSE OF FOUR LECTURES ON

SOME CHAPTERS IN MODERN BOTANY.

BY PROFESSOR JAMES SMALL, D.Sc., Ph.C., F.L.S.

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A COURSE OF FOUR LECTURES ON

THE GROUNDWORK OF THE UNIVERSE FROM A CHEMICAL STANDPOINT,

BY PROFESSOR A. W. STEWART, D.SC.,

Professor of Chemistry, Queen's University, Belfast.

IN CHEMICAL LECTURE THEATRE, QUEEN'S UNIVERSITY.

I.—THE FOUNDATION STONES OF MATTER.

One of the common actions of the human mind is the search for intrinsic resemblances between things which on the surface exhibit differences in character. Thus the chemist seeks to identify common characteristics in a group of materials, each of which differs from the others in its surface appearance. The great aim of the chemist is simplification, the breaking up of matter into forms which cannot be further decomposed. Thus water can be decomposed into two gases, oxygen and hydrogen, and neither of these gases has been further decomposed, so they are called "Elements," and to-day we recognise ninety-two such "Chemical Elements" as capable of existence. These elements are built up of particles called atoms, almost indefinitely small, the atoms in any one element being all alike in chemical properties; but the different chemical elements vary because of the different characters of the atoms from which they are formed.

Since these atoms are material bodies, they must have definite

masses and occupy definite volumes, so that we speak of the "atomic weight" and the "atomic volume" of an element.

In 1815 Prout suggested that the atoms of all elements are built up from those of hydrogen, which is the lightest known body. For almost a century Prout's views were rejected by the scientific world, but recent work tends to establish this hypothesis upon a more solid basis.

Towards the classification of these ninety-two elements the earliest definite work was due to the English chemist, Newlands, while at a later date, and apparently independently, Mendeléef and Lothar Meyer developed the system into its present form.

Suppose that the elements are arranged in ascending order of the weights of their atoms, and that alongside the names of the elements we place first the nature of the element and second the number of hydrogen atoms which one atom of the element will combine with or will displace from combination. We then get the following arrangement:—

TABLE I.

Atomic Weight correct to the nearest unit.	Element.	Nature of Element.	Number of Hydrogen Atoms combined with or displaced by one atom of the element.
4	*Helium	Inert gas	0
7	**Lithium	Light soft metal	1
9	***Beryllium	Heavier tough metal	2
11	Boron	Non-metal	3
12	Carbon	Non-metal	4
14	Nitrogen	Gas, not reactive	3
16	Oxygen	Gas, reactive	2
19	Fluorine	Gas, very reactive	1
20	*Neon	Inert gas like helium	0
23	**Sodium	Metal like lithium	1
24	***Magnesium	Metal like beryllium	2

An examination of the above Table brings to light a certain order in the arrangement. Thus helium, the first element, has properties similar to those of the ninth element, neon; the second

element, lithium, shows an analogy with the tenth element, sodium; whilst the third and eleventh elements, beryllium and magnesium, also show a close resemblance in properties. (The similar elements are indicated by one, two and three asterisks). Thus we can say that every eighth element in the series will have similar chemical properties, and that by such an arrangement we obtain a regular *periodicity*. The same type of element recurs at regular intervals in the series as in the notes of the musical scale, from which analogy Newlands called his system the "Law of Octaves."

A further periodicity is seen in the number of hydrogen atoms which one atom of an element will displace from combination, the figures rising regularly from zero to four and thence falling as regularly again to begin a new series with another zero. The following Table shows the system of classification now adopted :—

Table II.

The Periodic Arrangement of the Elements.

Group 0.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.		
Helium 4.0	Lithium 6.9	Beryllium 9.1	Boron 11.0	Carbon 12.0	Nitrogen 14.0	Oxygen 16.0	Fluorine 19.0			
Neon 20.2	Sodium 23.0	Magnesium 24.3	Aluminium 27.1	Silicon 28.3	Phosphorus 31.0	Sulphur 32.0	Chlorine 35.5			
Argon 39.9	Potassium 39.1	Calcium 40.0	Scandium 44.1	Titanium 48.1	Vanadium 51.0	Chromium 52.0	Manganese 54.9	Iron 55.8	Cobalt 59.0	Nickel 58.7
	Copper 63.6	Zinc 65.4	Gallium 69.9	Germanium 72.5	Arsenic 75.0	Selenium 79.2	Bromine 79.9			
Krypton 82.9	Rubidium 85.5	Strontium 87.6	Yttrium 88.7	Zirconium 90.6	Columbium 93.1	Molybdenum 96	—	Ruthenium 101.7	Rhodium 102.9	Palladium 106.7
	Silver 107.9	Cadmium 112.4	Indium 114.8	Tin 118.7	Antimony 120.2	Tellurium 127.5	Iodine 126.9			
Xenon 130.2	Caesium 132.8	Barium 137.4	THE RARE EARTH GROUP.		Tantalum 181.5	Tungsten 184.0	—	Osmium 190.9	Iridium 193.1	Platinum 195.2
	Gold 197.2	Mercury 200.6	Thallium 204.0	Lead 207.2	Bismuth 208.0	Polonium	—			
Niton 222	—	Radium 226	Actinium ?	Thorium 232.4	UX—2 ?	Uranium 238.2	—	—	—	—

The numbers under the names give approximately the relative weights of the atoms. No position has been assigned to hydrogen, which is sometimes placed above lithium, though reasons have been adduced which might lead to its classification along with fluorine. Only one radioactive element is shown for each place in the lower part of the Table, as it would occupy too much space to include all the members of each group of isotopes. Thus thorium represents the group: thorium, ionium, radio-thorium, uranium-X_1, and radio-actinium, all of which have identical chemical properties.

Hydrogen has been omitted from the table on account of the difficulty in placing it properly. From its chemical properties it should be situated above lithium, but for physical reasons it seems allied to fluorine at the other end of the line.

The table is so arranged that the vertical columns contain those elements which show a family resemblance to each other in their properties. Thus the inert gases are ranged together, and in the next column we find lithium, sodium, potassium, rubidium and caesium showing close family likenesses, while with them are copper, silver and gold which have many chemical characteristics in common with the other five.

This periodicity is also found in the volumes of the atoms. The curve at the end of this section shows a regular periodicity in volume and in other physical properties, when arranged in the same order as in the Table.

From this arrangement we get the conception of an "atomic order" in which hydrogen is the first element, helium the second, lithium the third, and so on to uranium, which is the ninety-second. The place which the element occupies is called its atomic number.

When the rays from the cathode of a Crookes' vacuum tube are allowed to fall upon a specimen of an element, an X-ray is produced, and the wave-length of this ray is characteristic of the element. Moseley has shown that the wave-length is reciprocally proportional to $A(N-1)^2$, in which A is a constant and N the atomic number of the element used. We can thus calculate the atomic number of the element and establish its place in the periodic system by this measurement alone. If from a complete series of such measurements we find any blanks in our table, we are able to say where the corresponding unknown elements will take their places when actually discovered. Moseley found there were five blanks upon the roll: (1) between molybdenum and Ruthenium; (2) between tungsten and osmium; (3) between polonium and niton; (4) between niton and radium; (5) one in the rare earth group, which is not shown in Table II. When

this result is compared with Mendeléef's table it is seen that blanks were actually left by Mendeléef at these very points. Thus two lines of evidence, chemical and physical, indicate that there are still five elements to be discovered.

In support of such forecasts we know that in 1871 scandium, gallium and germanium were unknown, but Mendeléef, from the gaps in his table, predicted the fact of their existence and even their very properties with amazing certitude.

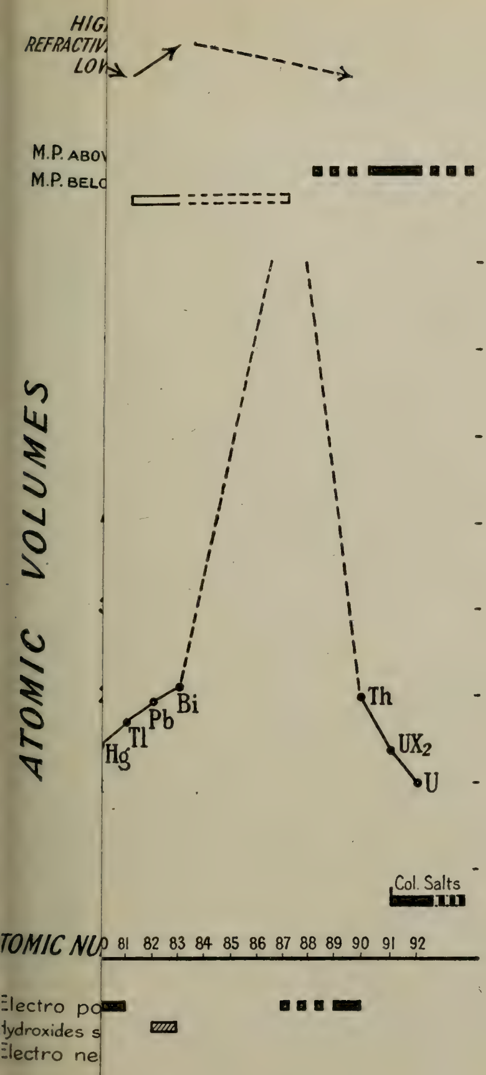
TABLE III.

Prediction (1871).	Properties of Germanium (1886).
Atomic Weight = 72.	Atomic Weight = 72·5.
Grey Metal, hard to fuse.	Grey Metal, fuses 900° c.
Specific Gravity = 5·5.	Sp. G. = 5·469.
Density of Oxide = 4·7.	Density of Oxide = 4·703.
Volatile liquid Chloride, boiling at 90°C. with density of 1·9	Chloride is a volatile liquid, boiling at 86°C. density 1·887.
Easily forms volatile Fluoride.	Fluoride volatile.

Thus from consideration of his periodic table Mendeléef was able to predicate the existence of an unknown element and even to forecast its properties with wonderful accuracy. He was equally successful with the other two elements, scandium and gallium.

These examples show the extreme importance of the classification in the Periodic Table. The actual causes of these variations are not yet known, but in the future we may learn something of the laws which have been thus revealed.

[To indicate the resemblances between members of the same group of elements many experiments were shown, among them vacuum tubes of the rare gases, tints imparted to a Bunsen flame by the presence of lithium and its congeners, while other resemblances were illustrated by the formation and non-formation of precipitates on the addition of certain reagents.]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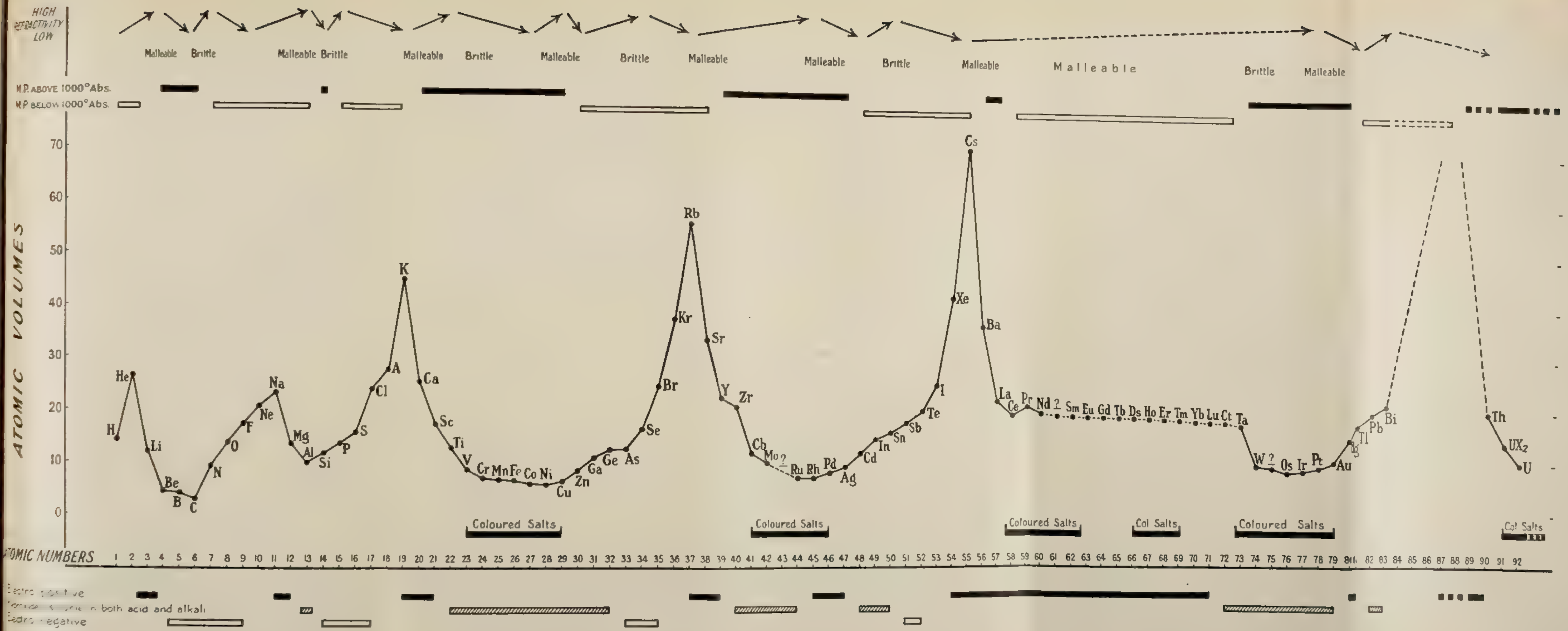


From "Recent Advances in Physical and Inorganic Chemistry," by Professor A. W. Stewart, D.Sc.

II.—THE RISE OF RADIO-ACTIVITY.

The beginnings of the science of radio-activity must be dated from 1879, when Sir William Crookes published the results of his investigations upon the passage of an electric discharge through highly evacuated tubes. Previous to this time it was known that a spark passed between two electrodes at atmospheric pressure became broadened out into a columnar form as the pressure became reduced, so that when a discharge was passed between the electrodes of a tube containing a gas at a moderately low pressure, the whole tube glowed brilliantly.

Crookes showed that when the evacuation is carried to a very high degree and only a very slight amount of residual gas remains in the tube, the glow vanishes and the interior of the tube becomes almost non-luminous. At the same time a green fluorescent light makes its appearance on the glass of the tube opposite the cathode.

Certain "rays" originate at the cathode, leave its surface at right angles and travel in straight lines through the tube until they impinge upon the glass, the green fluorescence occurring at the points of impact. The following evidence determines the character of these rays. They leave the cathode only on the side nearest the positive electrode, and do not spread in all directions like the radiations from a heated body. If an aluminium cross be interposed in the path of the "rays" a shadow of the cross is thrown on the patch of green fluorescence, showing that the "rays" are either vibrations like light or are streams of particles. If a tiny windmill be placed in the path of the "rays" it spins with great velocity, in a manner not to be explained by "light pressure," but easily understood if there be a stream of particles. But the "rays" can be deviated from their straight path by means of a magnet or an electric field, which indicates that they are jets of particles each carrying an electric charge. These charges are negative when examined by an electroscope. Finally, investigation shows that these particles have, almost

certainly, a mass seventeen hundred times smaller than a hydrogen atom, and that they are really corpuscles of negative electricity which we call *electrons*.

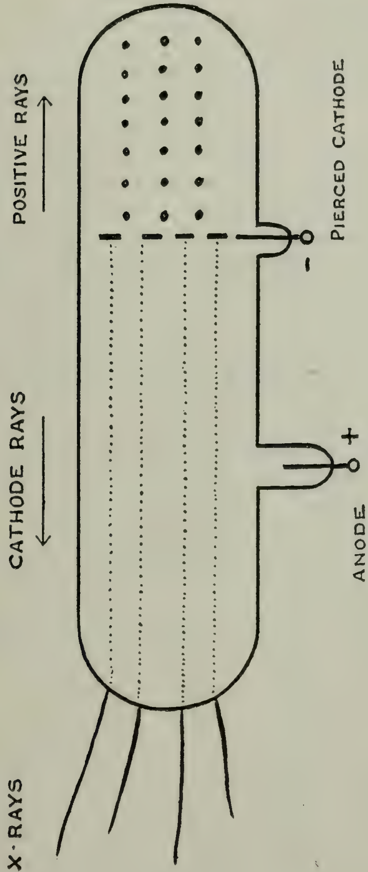
But another set of phenomena has been observed in the Crookes' tube.

If the cathode be pierced with a series of apertures, a second set of "rays" makes its appearance, travelling in the direction opposite to that of the cathode rays. These are shown to be streams of the molecules of the gas in the tube, each carrying one or more positive charges, being named for this reason "Positive Rays." In the dark they can be seen as faint pencils of light traversing the tube.

There is still a third type of "ray" observable, the X-rays. These are rays of light of extremely short wave length, related to ordinary light as a note in the treble of a piano is to a note in the bass. They are produced by the impact of electrons upon matter, and in the Crookes' tube they originate where the cathode rays strike the glass of the tube. They have the power of making the air through which they pass a good conductor of electricity.

Both Dr. R. Beattie and Dr. P. T. Crymble, of the Queen's University, have made valuable contributions to our knowledge in this sphere, the one in pure Physics, the other in the applica tion to medical and surgical problems.

In 1896, the French scientist, Becquerel, was struck by the resemblance of the green fluoresence of Crookes' tubes to the fluoresence of certain salts of uranium, and it occurred to him that these salts might be emitting X-rays. We know now that his analogy was erroneous; but when he tested these salts by the photographic method, he found that there actually was an emission of X-rays. This discovery by Becquerel opened up an entirely new field of research, lying within the borders of both Chemistry and Physics; and at once there was a rapid extension of our knowledge. Other elements, such as thorium, were found to be radio-active, this being easily demonstrated by laying a


POSITIVE RAYS
PIERCED CATHODE
CATHODE RAYS
ANODE
X-RAYS
+
-

broken fragment of an incandescent mantle, containing oxide of thorium, upon a photographic plate and leaving it in the dark for a week. On development the plate will show the reticulations of the mantle. Soon the new element actinium was discovered, and Mme. and M. Curie isolated the salts of radium from pitch-blende.

After months of laborious work it was shown that radium was chemically closely related to barium, since it was extremely difficult to separate these two elements, though it was comparatively easy to isolate the radium-barium group from all the other elements in pitch-blende. Some idea of the labour involved may be got from the fact that from one ton of the material less than the thirtieth of an ounce of very impure radium salt was obtained.

The chemical resemblance between radium and barium shows they belong to the same group in the Periodic System, and it is seen that radium lies just below barium in Group II of this classification. The other radio-active elements have positions in the table between lead and uranium, so that their atomic weights are all high. Potassium and rubidium form exceptions, and investigation in their case is still incomplete.

It is found that radium compounds have properties different from those of other elements. They break up water just as electricity does; their temperature is always slightly higher than that of their surroundings; they colour glass vessels in which they are kept, and they give off the "rays" which are called Becquerel rays. Finally, radium salts emit a radio-active gas, niton, which will be dealt with in the next lecture.

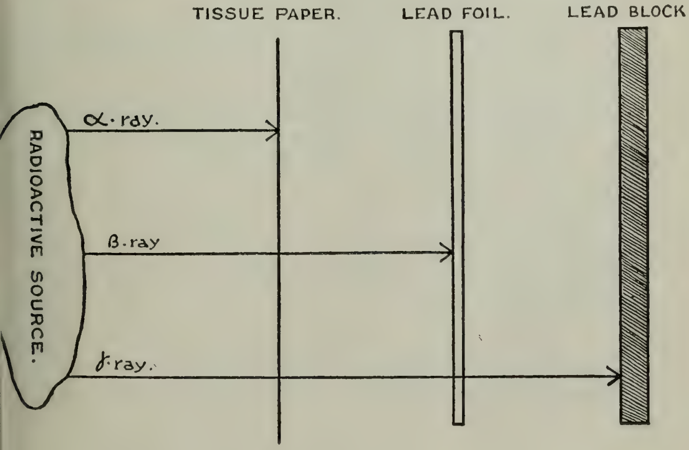
A simple experiment shows that no less that three types of "ray" are emitted by radio-active materials. A sample of a radio-active salt is allowed to radiate upon an electroscope, and the rapidity of discharge of the electroscope is observed. If, now, a sheet of cigarette paper is wrapped about the salt, and the observation repeated, it is found that there is a marked diminution in the rate of discharge. Thus a fraction of the

"rays" has been trapped and prevented from reaching the electroscope. If a second sheet of paper is added, it is found that the rate of discharge is unaltered, so it appears that the first sheet of paper screened out entirely some constituent parts of the "rays," and that the part passing the paper penetrates a second sheet just as easily as the first.

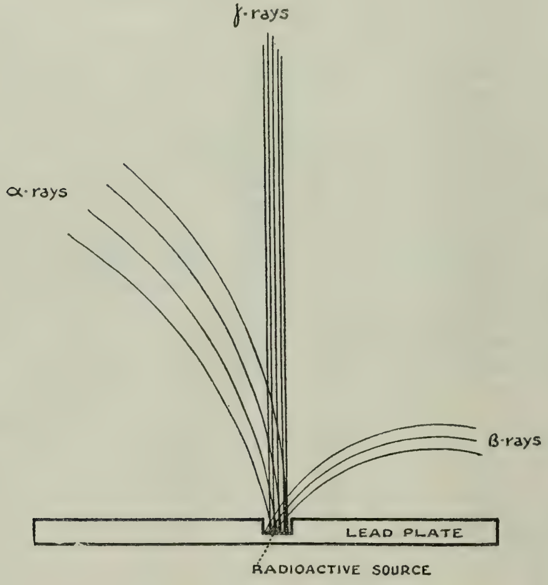
Thin lead foil causes stoppage of much of the radiation which passed the paper, but a second thin sheet has no further action. A heavy lead block, however, cuts off all the "rays." Thus there are three constituents: one which passes the paper but not the lead foil, one which is stopped by the heavy lead block after passing through the lead foil, and finally those "rays" which failed to pass through even the paper.

The component stopped by thin paper is called the *Alpha-ray*, that stopped by lead foil after passing through the paper, the *Beta-ray*, whilst the most penetrating component is the *Gamma-ray*.

To put the matter in the form of a diagram we have something like Fig. II as a representation of the experimental results.



When a magnetic field is applied to a thin pencil of the Becquerel rays the pencil is split up into three different sprays as shown in Fig. III.



The Gamma-rays are almost unaffected by the magnetic field ; the Alpha-rays are slightly deviated, while the Beta-rays are more strongly affected.

The Alpha rays are deflected on to the right, the Beta to the left of the original direction, which the Gamma-rays continue to pursue, unaffected by the magnetic field.

Recall now the three types of ray from the Crookes' tube, the Cathode-ray, the Positive-ray, and the X-ray. Each of these has the same qualities as one of the constituents of the Becquerel rays, corresponding as below :—

Becquerel Rays.	Crookes' Tubes.
Alpha-rays,	Positive-rays,
Beta-rays,	Cathode-rays,
Gamma-rays,	X-rays.

The Alpha-rays are atoms of helium, each atom carrying two charges of positive electricity; the Beta-rays are streams of negative electrons, while the Gamma-rays are really X rays having a penetrating power far in excess of any we can produce artificially. Some idea of the enormous velocities of emission may be got from the following figures :—

Alpha particles	...	20,000	miles	per second.
Beta ,,	...	170,000	,,	,,
Light	...	186,000	,,	,,

A little reflection will suggest the reason of the phenomena observed in radio-active centres. The Alpha particle, ejected from the radio-active atom at a very high velocity soon strikes some heavier matter in the form of atoms in the radio-active mass and heat is thus generated, so that these helium atoms will tend to raise the temperature of the material with which they collide, and keep it permanently above that of surrounding bodies. Again, radio-active materials eject showers of electrons travelling much faster than the Alpha particles. When these strike matter they generate X-rays, as the cathode stream of a Crookes' tube did at its point of contact with the glass, so that there is a complete parallel between the action of the Becquerel rays and that of the Crookes' tube.

To sum up the properties exhibited by the Becquerel rays as a whole—They have the power of ionizing gases and making

them conduct electricity readily; they produce photographic effects upon sensitive plates, even through cardboard; they cause zinc sulphide to glow strongly, as is seen in the ordinary luminous watch or compass; they colour glass violet or brown according to its chemical composition, and they have a powerful disintegrating action on vital tissue.

This last property is utilized in radium therapy, which is successful in the case of rodent ulcer and similar diseases. The radio-active material, usually the gas niton, is enclosed in a tiny tube within a silver sheath and introduced into the wound. The violent action of the rays destroys the diseased tissue, and it is possible for fresh healthy tissue to grow in its place.

There is another property of radium which requires attention. The radium atoms are constantly breaking up, so that, although radium is an "element," it is not a permanent body. Half disappears in 1,350 years, so that in 2,700 years only one-fourth will be present, and in another 1,350 years only one-eighth. If, then, there is now in existence one gramme of radium, and if it be the descendant of a pre-existing mass, this mass, no longer than 140,000 years ago, must have been as large as the earth, a conclusion which all the facts of geology show to be absurd. It must therefore be assumed that radium has a parent, from which it is being continually derived. Just as the gas niton is a descendant of radium, so is radium itself a product of ionium, which is in turn descended from yet another elementary form of matter.

Thus a certain family relationship among the radio-active elements can be traced, which will be dealt with in the next lecture.

In conclusion, it seems worth while to draw attention to the immense practical benefits which have followed the investigations in this one field of research, investigations which have their origin in University laboratories, and which were undertaken only from a pure love of knowledge for its own sake.

The discovery of the X-rays, with all their modern applications to medical and surgical problems, arose directly from Sir William Crookes' desire to know what results follow from the evacuation of tubes to a higher degree than had ever been tried before. The whole investigation of radium therapy arose from Becquerel's study of the uranium salts, again a problem of a purely scientific nature, seeming then to have no practical bearing. The self-luminous compass, serving to guide our airmen in their night flying, and to permit our battleships to cruise in the darkness without showing a light, was the result of Sir William Crookes' invention of the spinthariscope, designed to make visible the impact of the alpha particles by their action on zinc sulphide.

The search of knowledge for its own sake and without ulterior motives actually lays the foundation for the most unexpected and valuable practical applications. No applied chemist would ever have dreamed of searching for a radio-active material before Becquerel's discovery, nor would he have thought of devising an apparatus by means of which the bones of the living hand could be examined, until the X-rays were actually discovered in a laboratory.

The words of Huxley are true to day as when spoken, "I would make accessible the highest and most complete training the country could afford. Whatever might be the cost, depend upon it the investment would be a good one. I weigh my words when I say that, if the nation could purchase a potential Watt, or Davy, or Faraday, at a cost of a hundred thousand pounds down, he would be dirt cheap at the money. It is a mere commonplace and every day piece of knowledge that what these three men did has produced untold millions of wealth, in the narrowest economical use of the word."

With this in view it is right to acknowledge with gratitude the generosity of Mr. F. A. Heron, who has presented to the Queen's University a most munificent gift for the proper equipment of a department for Physical Chemistry, and has thus enabled the University to furnish Ulster students with a training in this

most important branch which will allow them to compete on even terms with graduates from other Universities. It is especially appropriate that the Heron gift should have been devoted to a branch of Chemistry with which the name of Belfast is connected through the fame of Andrews.

III.—THE TRANSMUTATION OF THE ELEMENTS AND KINDRED PROBLEMS.

In the first of this series of lectures, it was tacitly assumed that what we call "chemical elements" are forms of matter which exist unchanged through their history and which are not capable of decomposition into simpler materials. With the second lecture in the course, following the historical development of the subject, it was found necessary to modify this view in order to bring it into line with modern work on the radioactive elements: for these forms of matter have been found to disintegrate spontaneously into simpler substances, though the experimental resources at our disposal fail to initiate such decompositions among the non-radioactive elements or even to influence the rate at which the radioactive elements disintegrate. In the present lecture, the subject will be brought up to date and the discoveries of the past year will be described, which show that even this voluntary break-down of certain elements is possible at the present time. But before entering upon this field, it may be well to go back to the beginning of the century, when Sir William Crookes was investigating the radioactive properties of the element uranium.

Crookes found that a certain specimen of uranium showed marked radioactive character; but when he applied the processes of chemical analysis to it, he was able to separate it into two parts. The one portion showed strong beta-ray activity (like the parent specimen); but the second portion exhibited no beta-ray activity whatever. After being left aside for some months, however, the non-active specimen was found to have acquired radioactive pro-

perties and to display considerable beta-ray activity. These results are expressed in the following scheme :—

ORIGINAL "URANIUM."
(Gives off β-rays)

URANIUM-1
(Emits no β-rays)

On standing

URANIUM-X_1
(Emits β-rays)

URANIUM-X_1
(Emits β-rays)

There is nothing abnormal in the separation of "uranium" into two fractions, one of which is radioactive whilst the other is inactive ; for the radioactive material might be there as an impurity in the original mass of "uranium." What *is* extraordinary is the fact that after all the radioactive impurity is removed, the remaining inactive material gradually becomes *again radioactive.* This is practically parallel to the complete removal of silver from a lead-silver alloy and the slow reappearance of silver after a time in the carefully purified lead. It can be accounted for only by assuming that the substance uranium-1 is breaking up and giving rise to a new element, uranium-X_1, which possesses beta-ray activity.

The phenomena mentioned in the last lecture in connection with radium throw further light upon the matter. Radium, it was found, gave off continually a gas, niton, which has radioactive properties different from those of radium itself. Here, obviously, since both radium and niton are known to be elementary forms of matter, we have the case of one element giving birth to another ; and the older idea of the permanence of the elements has received a severe shock.

When the chemical properties of niton were investigated by Sir Ernest Rutherford and Mr. Soddy, it was found that they

formed an exact parallel to those of the inert gases of the atmosphere discovered by Sir William Ramsay. Niton refuses to combine with any other element, even when heated to a red heat in the presence of reactive metals. It thus shows itself akin to argon and its congeners of the Zero Group in the Periodic Table.

But while thus chemically inert, niton is very powerfully radioactive. When it is dissolved in water, it decomposes the liquid into oxygen and hydrogen, just as the electrodes of a battery do. It sends out a very intense stream of alpha-particles, with all the properties which such emitted particles ordinarily display. It affects a charged electroscope when brought near to it; and it causes a fluorescent screen to glow brightly when the gas is blown across the surface.

In order to handle niton, special precautions had to be taken. In the course of the fundamental experiments of Sir William Ramsay and Mr. Soddy, the largest volume of niton obtainable was about 0·000,000,32 cubic inches; and the manipulation of this tiny bulk of gas was extremely difficult. In order to transfer the niton from vessel to vessel, it was necessary to mix the radioactive gas with a large bulk of air and then drive the mixture from its reservoir to the place where it was required. In this way the loss of a fraction of a cubic inch of the mixture only represented the mislaying of an immeasurably small quantity of niton.

Sir William Ramsay, however, actually manipulated pure niton, unmixed with air. Working merely with the almost invisible volume mentioned above, he and Dr. Whytlaw-Gray were able to liquify and solidify niton, determine its critical temperature and pressure, and study its behaviour under the microscope as it passed from state to state.

In order to fix definitely the place of niton in the Periodic Table, it was necessary to determine its atomic weight; and the only way in which that could be done was by the determination of the gaseous density of the element—i.e., by weighing a known volume of the gas. The experimental difficulties in the way of

this were so great that it was generally assumed to be an impossible task; but Sir William Ramsay and Dr. Whytlaw-Gray were not deterred by this idea: and they proceeded to construct a "microbalance" capable of weighing the extremely small quantity of niton available. This balance, when eventually constructed (from quartz fibres) was so delicate that it turned with the weight of 0·000,000,04 ounces. Its construction marks the high-water mark of accuracy in weighing ever successfully performed. Of course, no weights could be prepared of sufficient refinement to use on a balance of this accuracy; but Sir William Ramsay overcame this difficulty by utilising as his weight a glass tube filled with air at ordinary pressure, and by making his balance-case air-tight and capable of evacuation. When the air in the balance-case was at ordinary pressure, obviously the air in the "weight" had no effect; but when the air was pumped out of the balance-case then the "weight" depressed the beam, because the air inside the glass "weight" was no longer equipoised with the air outside the "weight." Thus by measuring the pressure of the air in the balance-case, it was possible to calculate the exact "weight" of the glass tube, plus the air inside it. By means of this balance the exact weight of the tiny quantity of available niton was ascertained; and when its atomic weight was calculated from this it was found that the atom of niton was 222 times heavier than a hydrogen atom—a figure which brings niton into the bottom of the inert gas column of the Periodic Table.

It will be noticed that the word Niton has the same termination as most of the other elements of the group. The name was given to it because of its luminosity. In the dark a tube of niton glows with a greenish-white lustre; and on this account Ramsay called it Niton—the shining one. It was originally termed "radium emanation."

The decay of the element niton is extremely rapid. In ninety-four hours half of it disintegrates, no matter what quantity we start with at first. In the next ninety-four hours it falls again

to half its quantity. Thus, if at the start there were sixteen grammes of niton present, the following figures give the amounts remaining in existence after various periods :—

Start	... ...	16 grammes.
After 94 hours	..	8 grammes.
After 188 hours	...	4 grammes.
After 282 hours	...	2 grammes.
After 376 hours	...	1 gramme.

It is now necessary to deal with the work of Sir William Ramsay and Mr. Soddy upon niton. Hitherto, though the change of one element into another had been well-established—as has been described above—both the parent and the descendant elements had belonged to the radioactive group, which at that time were regarded as forming a class apart from the ordinary chemical elements. Sir William Ramsay and Mr. Soddy, however, brought the matter into a new orientation by proving that niton, in the course of its disintegration, produced a perfectly well-known element, helium. This formed the first link connecting the radio-elements with the common non-radioactive series of elementary materials known to chemists.

Suppose that we had, enclosed in a glass tube, some niton, and that we were able to measure the pressure of the gas within the tube from day to day. This was actually done by Sir William Ramsay and Mr. Soddy ; and, somewhat to their astonishment, they found that the pressure diminished as time passed. Finally, on examining the spectrum of the contents of the tube, they observed that the niton spectrum had disappeared completely, and had been replaced by that of helium.

Further investigation shows that the walls of the tube have acquired radioactive properties. That these properties are due to a solid deposited on the glass can be proved in various ways. For example, if the glass be scraped with a metal point, the metal in turn acquires the power of discharging an electroscope ; or again, by means of acids it is possible to dissolve from the glass

some material which displays radioactivity. Thus niton clearly disintegrates and gives rise to some solid material, Radium A, which is also radioactive like its parent.

The next question which arises concerns the helium found in the tube. Where does it come from? To discover this we must go back to the alpha-particles which form part of the Becquerel rays. These alpha-particles are helium atoms carrying two charges of positive electricity; and since niton shows very strong alpha-ray activity, it is not hard to deduce that the helium found in the tube by Ramsay and Soddy was simply a collection of the helium atoms ejected from the niton in the course of its disintegration. Thus we may symbolise the break-down of radium and its descendants in the following way:—

TABLE III.

Solid	RADIUM Atomic Weight 226	→	HELIUM Atomic Weight 4	Gas
	↓			
Gas	NITON Atomic Weight 222	→	HELIUM Atomic Weight 4	Gas
	↓			
Solid	RADIUM-A Atomic Weight 218			

Thus the atom of radium, in disintegration, gives rise to an atom of helium and an atom of niton; and the atom of niton is four units lighter than the radium atom, since the remainder of the weight of the radium appears in the helium atom, with atomic weight 4. In turn, the niton atom throws off four units of weight in the guise of a helium atom and the remainder of the exploded atom is the atom of radium-A, with atomic weight 218.

The diagram above gives us the idea of a "radioactive series," that is, a series of elements each of which is born from one heavier than itself, and may give rise in its turn to some

lighter element. Originally three of these series were assumed to exist, one starting from uranium, another from the element actinium, and a third from thorium ; but recent work by Professor Soddy has proved that there are only two, since actinium itself is a descendant of radium.

The following Table IV shows the relations of the radio-elements, and gives some idea of the number of these unstable materials now known :—

Table IV.

THE RADIOACTIVE SERIES OF ELEMENTS.

I.—The Thorium Series.

Element	Atomic Weight	Average Life	Rays Emitted
Thorium	232	$2 \cdot 6 + 10^{10}$ years	α
Mesothorium-1	228	7·9 years	β
Mesothorium-2	228	8·9 hours	β
Radiothorium	228	2·91 years	α
Thorium-X	224	5·25 days	α
Thorium emanation	220	78 seconds	α
Thorium-A	216	0·2 seconds	α
Thorium-B	212	15·4 hours	β
Thorium-C	212	87 minutes	α and β
Thorium-C^1	212	10^{-11} seconds	α
Thorium-D	208	4·5 minutes	β
End-product	208	Permanent	No rays

Note.—Thorium D and Thorium C^1 are both disintegration products of Thorium-C which decomposes in two different ways.

II.—The Uranium-Radium Series.

Element	Atomic Weight	Average Life	Rays Emitted
Uranium-1	238	8×10^9 years	α
Uranium-X_1	234	35·5 days	β
Uranium X_2	234	1·65 minutes	β
Uranium-2	234	3×10^6 years	α

Element	Atomic Weight	Average Life	Rays Emitted
Ionium	230	2×10^5 years	α
Radium	226	2,440 years	α
Niton	222	94 hours	α
Radium-A	218	4·3 minutes	α
Radium-B	214	38·5 minutes	β
Radium-C	214	28·1 minutes	α and β

At this point a branching occurs in the series. Radium-C disintegrates by two different processes, yielding respectively Radium-C^1 and Radium-C_2. Each of these then disintegrates as shown below.

Radium-C^1	214	10^{-6} seconds	α
Radium-D	210	24 years	β
Radium-E	210	7·20 days	β
Radium-F	210	196 days	α
End-product	206	Stable	No rays

Radium-C_2	210	1·9 minutes	β
End-product	210	Stable	No rays

III.—The Uranium-Actinium Series.

Element	Average Life	Rays Emitted
Uranium-Y	2·2 days	β
Uranium-Z (Eka-tantalum)	?	α
Actinium	5,000 years	β
Radioactinium	28·1 days	α
Actinium-X	16·4 days	α
Actinium emanation	5·6 seconds	α
Actinium-A	0·003 seconds	α
Actinium-B	52·1 minutes	β
Actinium-C	3·1 minutes	α
Actinium-D	6·83 minutes	β
End-product	Stable	No rays

Note.—Uranium-Y is believed to be derived from Uranium-1, but the exact connection has not yet been traced. The atomic weights in the actinium series have not been determined up to the present.

The actual positions of all these elements in the Periodic System were established for the most part by the work of Dr. Fleck, who carried out the most extensive investigation in this difficult region of the subject. Some idea of the complexity of the problem solved by him may be gained from the fact that certain of the elements which he examined fall to half their original quantity in an extremely short time. A gramme of radium-A, for example, will leave only half a gramme undecomposed after four minutes and twenty seconds. Thus Dr. Fleck had not only to cope with the normal difficulties of assigning to an element its proper position in the Table but in addition he had to work with the greatest rapidity if any measurable quantity of his material was to be left intact at the end of his experiments.

On the basis of Dr. Fleck's results, which were obtained in Soddy's laboratory, Prof. Soddy put forward the generalization now known as Soddy's Law; but before the enunciation of this is given it may be best to examine a simple case which is already familiar to us.

Radium belongs to Group II of the Periodic Table. In disintegrating, it ejects an alpha-particle and is converted into niton, which occupies a position in the Zero Group of the Table. Further, since the ejection of the helium atom entails the loss of four units of atomic weight, niton is four units lighter than radium. *Thus in the case of what is called an "alpha-ray change" the descendant element occupies a position in the column next-but-one to the left of the parent; and the atom of the descendant is four units lighter than that of the parent element.*

On the other hand, when an element changes into another by the ejection of an electron (Beta-ray change), the descendant occupies a position one column to the right of the parent.

The italicized text above gives the Soddy Law, which governs the character of the relations between the parent element and its descendant as far as the Periodic Table is concerned.

Professor Soddy, however, was not content merely with the enunciation of this Law. He proceeded, as Mendeléef had done, to predict certain results which must follow if his views were correct; and the fulfilment of his prediction has marked almost as great a stride forward in our knowledge of the atom as that which the Russian chemist made in connection with the relations between the elements.

The stable product which finally results from the radioactive disintegration of uranium is a material having all the chemical properties of lead. The end-product of the thorium series is also chemically indistinguishable from lead. Now, in order to attain the stage of lead, as Professor Soddy pointed out, uranium has to eject eight alpha-particles; whilst thorium yields lead by the ejection of six alpha-particles. Since each alpha-particle is a helium atom with an atomic weight of four, it is evident that the lead from uranium will have an atomic weight thirty-two units lower than that of uranium; whilst the lead from thorium will have an atomic weight twenty-four units less than that of thorium itself:—

Atomic Weight			Atomic Weight
238·2	URANIUM	THORIUM	232·4
– 32 units	Loss of eight atoms of helium ↓	Loss of six atoms of helium ↓	– 24 units
206·2	LEAD	LEAD	208·4

Chemically indistinguishable.

The Atomic Weight of natural Lead is 207·1.

Basing himself upon these facts, Professor Soddy predicted that although the lead obtained from uranium and that produced by the disintegration of thorium were chemically identical with each other, their atomic weights would be different: that of the uranium derivative being 206·2; whilst that of lead from thorium would be 208·4. This prediction has been tested with every

refinement of experimental skill by numerous workers ; and it has been proved to be correct.

It is evident that this work of Professor Soddy's revolutionises our previous ideas of the elements. Hitherto it has been assumed that all the atoms of an element were identical with each other in every respect ; but it is now conclusively established that two atoms, each of which has all the chemical properties of lead and each of which emits the same spectrum, have weights differing from each other by about one per cent. Since the two varieties of lead have identical chemical properties, they must both be placed in the same square in the Periodic Table ; and elements such as these are termed by Professor Soddy "isotopic elements" from *isos* = equal and *topos* = a place. The two varieties of lead are said to be *isotopes* of each other. Thus These isotopes, in some cases, are found to have different *radioactive* properties, though chemically they are inseparable from each other. Thus thorium is inseparable from uranium – X_1 by any chemical means ; but when the two are examined by radioactivity tests it is found that uranium – X_1 loses half its activity in thirty-five and a half days, whereas thorium requires many millions of years to decay to the same extent.

The recent work of Dr. Aston has shown that isotopy is not confined to the radioactive series of elements ; for even such common elements as chlorine are found to be made up of mixtures of atoms of different weights though they are all endowed with identical chemical properties.

Professor Soddy having thus established the existence of isotopy, it was my good fortune to call attention to the second half of the generalization upon which the modern classification of atoms is based. When a radioactive element parts with an electron in the beta-ray change, its atomic weight is unaltered, since in comparison with atomic weights, the mass of an electron is negligible. None the less, the loss of this electron produces a complete change in the *chemical* properties of the material. Evidently then, there may be two atoms of equal weights but

with entirely different chemical properties. To such atoms, I gave the name *isobares*, from *isos* = equal and *baros* = weight. To illustrate the question of isobarism, the following data will be sufficient :—

$$\text{Mesothorium-1} \xrightarrow[\text{Change}]{\beta\text{-ray}} \text{Mesothorium-2} \xrightarrow[\text{Change}]{\beta\text{-ray}} \text{Radiothorium}$$

AtomicWeight = 228 AtomicWeight = 228 AtomicWeight = 228

	Number of Hydrogen atoms displaced by one atom of element.	Element resembles.
Mesothorium-1	2	Barium
Mesothorium-2	3	Lanthanum
Radiothorium	4	Cerium

From the foregoing, the following possibilities are evident:—
Two elements having identical chemical properties are *isotopic.*
Two elements having different chemical properties are *heterotopic.*
Two elements having identical atomic weights are *isobaric.*
Two elements having different atomic weights are *heterobaric.*
By taking all the possible combinations of these in turn, the Soddy-Stewart classification of atoms is obtained :—

	Atomic Weights	Chemical Properties
Isobaric Isotopes	Same	Same
Isobaric Heterotopes	Same	Different
Heterobaric Isotopes	Different	Same
Heterobaric Heterotopes	Different	Different

Thus by means of this system we are able to define the relations between any two atoms, whether they are of the same elemental character or not and whether their weights are identical or different.

Leaving the work of the laboratory, it may be well to turn next to phenomena upon a far vaster scale. The resources of energy which the chemist and physicist have at their disposal are limited both in quantity and in intensity ; and it is necessary to examine certain astronomical evidence in order to gain a further knowledge of the behaviour of elementary matter under extreme

conditions. The views which are about to be described are due to Sir Norman Lockyer; and although they are not accepted *in toto* by the scientific world, they probably contain more than a grain of truth.

When investigating the emission spectra of metals, Lockyer found that the character of the spectrum emitted by an element depended to a large extent upon the temperature at which the metal was examined. Thus in a gas-flame having a temperature of a few hundred degrees, a certain metal gave a characteristic spectrum; in the electric arc, at a temperature of 3000°C, a different spectrum was exhibited by the same metal; whilst, finally, in the electric spark, which is supposed to have a temperature of some 12000°C., the metal shows yet another type of spectrum.

Lockyer's examination of star spectra suggested to him that among the stars there are bodies at all sorts of different temperatures; and he began to classify the stellar species into groups according to this property. At first sight it might appear to be impossible to determine which of two stars was the hotter; but the matter is not so difficult as it might seem at first sight. A simple example will make the matter clearer. Suppose that the complete spectrum were spread out by a prism as shown below:—

HEAT RAYS—RED—ORANGE—YELLOW—GREEN—BLUE—INDIGO—VIOLET—ULTRA-VIOLET. Now assume that a piece of metal, such as a poker, is gradually heated. In the first place, it begins to emit heat rays while still remaining black to our eye. Next, it gradually turns red, showing that the red part of the spectrum is being radiated from it. With a further increase of temperature, its colour becomes lighter, because it is now radiating orange as well as red rays. A higher temperature makes it glow bright red, for at this stage it is throwing out every variety of ray from the heat-rays down to yellow; and the joint action of all these produces on our eye the sensation of bright-red. Finally, if we still further raise the poker's temperature, it

becomes white-hot, which implies that it is radiating all the vibrations from the slow heat-rays up to the rapid waves of the violet. Clearly from this example it is evident that the relative temperatures of two pieces of heated iron can be gauged by the length of continuous spectrum which they emit : the further this spectrum extends towards the violet, the hotter the material must be.

By an examination of the stellar spectra, Lockyer was thus able to catalogue the stars into various groups, the members of each group having approximately the same temperature.

Basing his views upon this experimental evidence, Lockyer put forward what is known as his Meteoritic Hypothesis of stellar evolution. He assumed as a beginning, a swarm of cold meteorites travelling through empty space. As time passes, gravitation will act upon this swarm, gradually drawing the meteors nearer and nearer together; and the result of this process will be a series of collisions between the flying bodies and the consequent generation of heat. Imagine this process continued for a considerable period, and it is obvious that in the next stage of evolution we should find all the meteorites agglomerated together into a loose mass with a moderately high temperature. Still the force of gravity would act upon the material, tending to condense the mass more and more ; and with the increasing condensation and consequent increase in the number of impacts between the particles, the temperature would continue to increase until finally the whole of the material would be a flaming mass of gas. At this point, it has reached its highest temperature ; and its subsequent history will be one of radiation and cooling. Slowly it falls in temperature, passing successively but in the inverse order through all the temperatures through which it travelled on the up-grade ; until finally it is reduced to a cold globe, a dead star.

After classifying the stars according to his results, Lockyer found that in the dull, red stars, most of the ordinary metals were present (as was proved by means of the spectroscope) in the

same state as in the electric arc and in addition there were signs of the presence of carbon. In the next hotter stars, no carbon was detected, but most of the metals were spectroscopically recognisable as being in the same condition as in the electric spark. In the next set, of still higher temperature, many of the metals were absent and the two elements hydrogen and helium appeared in considerable strength. Finally, in the hottest, gaseous stars, no metallic traces are found; hydrogen and helium were strongly marked and in addition there were lines in the spectra which correspond to no elements known upon the surface of the earth. Lockyer symbolised this somewhat after the following fashion :

↑ TEMPERATURE RISING		↓ TEMPERATURE FALLING
	GASEOUS STARS. (Hydrogen, helium and unknown elements).	
↗		↘
HIGH TEMPERATURE STARS (Few Metals present)		HIGH TEMPERATURE STARS (Few Metals present)
∧		∨
MEDIUM TEMPERATURE STARS (Metals in "spark" state; No Carbon present)		MEDIUM TEMPERATURE STARS (Metals in "spark" state; No Carbon present)
∧		∨
LOW TEMPERATURE STARS (Metals in "arc" state; Carbon present)		LOW TEMPERATURE STARS (Metals in "arc" state; Carbon present)
∧		∨
COLD METEORS		COLD STARS

Thus according to Lockyer's hypothesis, the stars present us with a picture of the evolution of the elements. At first there are the cold meteors, having a composition very like that of the Earth. Then, with rise in temperature, due to inter-collisions

between the bodies, a star is formed which contains most of the ordinary elements at a temperature somewhere between that of the electric arc and the electric spark. A further continuance of the evolutionary process yields stars of a temperature at least as high as that of the electric spark; and in the hotter stars of this group carbon apparently ceases to be capable of existence, since it vanishes from the spectra. A further step upward in temperature results in the disappearance of many metals, so that the spectra become simpler. Finally, when the stars are so heated that they become "gaseous stars," even the metals cease to be stable at these tremendous temperatures and only the very simplest elements of low atomic weight such as hydrogen and helium (together, probably, with forms of matter even simpler than helium) exist at all. Then, as the evolutionary process proceeds and the flaming mass of gas cools down by radiating its heat into the depths of space, the cycle is reversed. Gradually a few metals appear in the stars; then more are generated as the bodies cool down; finally carbon comes into existence once more and the stars disappear from our view into the dark state which reveals nothing to our spectroscopes.

Let us now turn back to the laboratory and see if in recent research anything can be traced which is comparable to this process of evolution postulated by Lockyer among the stars. Evidently we must search for two phenomena: the simplification of elements into atoms of smaller mass such as hydrogen; and the building up of hydrogen into more complex materials.

In the problem of simplification the pioneer was Sir William Ramsay. Recognizing the tremendous store of concentrated energy which exists in the radio-elements, he endeavoured to utilize it in order to break up "complex" materials into simpler components. By allowing niton to act upon copper, he found that lithium made its appearance. At the time, this result was not received with any enthusiasm by some physicists, as they contended that there were no grounds in theory for supposing

that such a conversion of one element into another could be produced by the action of the alpha-particle from niton.

Last year, however, Sir Ernest Rutherford, working in a different field, was able to show that a collision between an alpha-particle and a nitrogen atom gives rise to some particles which have at most the mass of two hydrogen atoms. This evidence seems to indicate that the nitrogen atom is disintegrated during the collision and that some of its fragments are hydrogen atoms.* It thus appears that in the laboratory it is possible to decompose even one of the "stable" elements into simpler materials.

The question of elemental synthesis seems also to have been solved, though Professor Collie, who did the work, has never claimed success in this direction, preferring to give his results without hazarding any hypotheses as to their cause. He showed that when electrical discharges are passed through hydrogen at low pressure in a tube, much of the hydrogen vanishes and helium makes its appearance in the vessel. Every test was applied which would prove leakage in the apparatus. For example, the discharge tube was surrounded by another tube and the space between the two tubes was completely evacuated; yet the helium still appeared in the inner tube when the discharge was passed through the hydrogen. Other checks were applied which would have established the existence of a leak even if the actual orifice were too small to be detected. In view of these results, it seems most probable that under the influence of the discharge some of the hydrogen is built up into helium; for no other hypothesis can account for the facts. If this be the correct explanation, Collie's results form a laboratory parallel to Lockyer's "down-grade" process in stellar evolution; for in the gaseous stars we have vast masses of gas, much of which is hydrogen, under very low pressures and subjected to violent electrical stresses—if the electrical and magnetic conditions of the solar globe be assumed in the stars.

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* This result appears to confirm Prout's view that atoms are built up from hydrogen.

The development of radioactivity has thrown light upon another science : geology ; and it is now possible to calculate the minimum period during which certain geological strata have remained undisturbed. How this is done can be made clear by a simple example.

Suppose that into a sealed flask a quantity of pure uranium-1 be introduced. In the course of its disintegration, this element will give rise on the one hand to helium and on the other to lead, as the end product of its degeneration. Since the process goes on at a mathematically calculable rate, it will be possible at any moment to ascertain how long it was since the experiment started, provided that we know (*a*) the quantity of uranium-1 left unchanged ; (*b*) the amount of helium or of lead present. The factor (*b*) tells how much uranium-1 has disintegrated ; and by adding that to the value in (*a*) the total amount of uranium-1 originally present is found. Thus we know the amount of uranium-1 originally present and we know also the quantity which has disintegrated during the period of confinement in the flask : these data suffice for the calculation of the period which has elapsed since the flask was closed.

Now in Nature, the flask is replaced by a mass of rock in which some uranium is imbedded. We analyse this rock and estimate in it the quantity of helium occluded in the pores of the mineral and we also determine the amount of lead present. Our analytical results give us all the data required for the calculation of the period which has elapsed since the uranium became enclosed in the stratum. It should be noted that since some of the helium may have diffused through the material of the rock, and thus become lost, the period calculated from the uranium-helium ratio in the rock is a minimum value. On the other hand, when the age of the rock is determined from the uranium-lead ratio in the mineral, it must be borne in mind that we are making the assumption that *all* the lead present has been derived from uranium ; whereas actually there may have been some ordinary lead present along with the uranium at the start. In the case of

the uranium-lead ratio, therefore, the figures represent the maximum time which can have lapsed since the stratum was iaid down and are possibly an over-estimate of this period. The results which have been obtained by the present Lord Rayleigh and others in this way may be given here :—

STRATA	Age deduced from $\frac{\text{Helium}}{\text{Uranium}}$ ratio	From $\frac{\text{Lead}}{\text{Uranium}}$ ratio
Miocene	6,300,000 years	30,000,000 years
Eocene	31,000,000	70,000,000
Carboniferous	146,000,000*	330,000,000
Devonian	145,000,000*	390,000,000
Archaean	405,000,000	940,000,000

In another field of geology, radioactivity has played its part. The rate of cooling of the Earth and Sun presents peculiarities which in the pre-radioactivity days could hardly be explained in a satisfactory manner. We now know, however, that the quantity of radium and other radioactive materials in the Earth is sufficient to account for the maintenance of the terrestrial globe's temperature for a much longer period than could be deduced from the ordinary physics of contraction and radiation ; and thus a difficulty has been removed from the path of Science in this region.

In closing an account of the progress of radioactivity, some mention must be made of the ramifications which the subject has produced. In physics, the radioactive properties of matter have led to the development of new views of the constitution of matter and have helped in the advance of our ideas of the atom. Chemistry has been assisted in its definition of the chemical elements and has seen its conceptions of the atoms revolutionized from the radioactivity side. In medicine, radioactive elements are now a recognized weapon in the cure of certain diseases; and

* It must be remembered that specimens from different localities are likely to vary in age, which perhaps accounts for the inverted order of the Carboniferous and Devonian results in the case of the uranium-helium ratio of these two. Also, as already mentioned, leakage of helium may have taken place in some of the specimens examined,

possibly even wider applications in this field are before us. In geology, radioactivity has given us a new method of measuring the duration of the periods of the Earth's history; and in Astronomy the radioactive phenomena have thrown fresh light upon the problems of stellar and terrestrial heat. Finally, aeronautics has profited with the rest; for the helium which arises from radioactive materials buried deep in the Earth's crust is now being utilized for filling airships with a light and non-inflammable gas.

IV.—SOME PROBLEMS OF FOOD AND POWER.

[The reader is also referred to Dr. A. K. MACBETH, "*Catalysis*," p. 34, Proceedings of Society, 1919-20; and to Professor WILLIAM CALDWELL, "*Fixation of Nitrogen*," p. 5, Proceedings of Society, 1917-18.]

Our modern civilization depends for existence upon its supplies of food and power. It is essential that our teeming populations must be fed, while the mere distribution of foodstuffs involves the expenditure of mechanical energy on a vast scale; for this reason these subjects were selected as suitable for this fourth lecture.

The question of food is the more important and may be dealt with first. The main task in the future will be the production of a greater yield of foodstuffs to provide for the constantly increasing population. This object may be obtained in two ways, either by an increased productivity of the soil, or by the manufacture of artificial foodstuffs by chemical means.

Our daily food consists of two main groups of materials: carbohydrates and proteins. Sugar, starch, &c., are carbohydrates, while cereals and meat contain large proportions of proteins. The carbohydrates contain only carbon, hydrogen and oxygen; while the proteins, in addition to these three, have nitrogen also as one of their components.

The human body contains between fifteen and twenty per cent. of nitrogen, and can neither be built up nor maintained in working order by a pure carbohydrate diet. Proteins are essential to life and nitrogen must be supplied to the animal frame if life is to be kept in existence.

But our bodies can make no direct use of the nitrogen which forms four-fifths of the air around us; we breathe it but expel it again unchanged. Nor can we utilize the simple nitrogen compounds. Nitrogen must be supplied in the form of the proteins which make up a large part of both animal and vegetable tissue. Our vital mechanism seems incapable of profiting by nitrogen unless presented in the form of protoplasm, which is a mass of extremely complicated chemical derivatives of nitrogen.

Human diet is partly vegetable and partly animal, but if the animal part of it is traced back it will be found to depend ultimately upon the vegetable kingdom. Thus the nitrogenous compounds have been traced back to the plants; but where do the plants themselves obtain the nitrogen for their tissues? In the majority of cases plants are unable to tap the store of nitrogen in the atmosphere. Some, like peas, beans, &c., are actually able to utilise nitrogen drawn direct from the air, but as a whole the nitrogenous supplies are derived by plants from the earth by means of their roots. Vegetables are in this way able to assimilate the simple compounds of nitrogen, such as ammonia, nitrites and nitrates, and to build the nitrogen thus obtained into the complex derivatives which the animals can utilise as food. The main reservoir of nitrogen is the atmosphere, from which certain bacteria and some plants are able to draw nitrogen which the plants convert into the organic compounds from which vegetable tissue is built up. When the plants die their protoplasm is broken up, either spontaneously or by the act of digestion of some animal which has swallowed the plant. The nitrogen then yields the derivative ammonia, containing one nitrogen and three hydrogen atoms.

If this ammonia is returned to the soil it is attacked by

certain "nitrifying bacteria," which have the power of converting the ammonia into nitrous acid, and thence again into nitric acid. The salts of these acids, not the acids themselves, are found in the soil.

In the form of a nitrate, nitrogen is easily assimilated by plants, and begins again the cycle in which once more it can be utilised by the animal. But in actual practice we find a different state of affairs. Part of the nitrites and nitrates is attacked by another class of bacteria, known as "denitrifying bacteria," which set free elemental nitrogen, of no use for either animal life or that of the majority of plants. Then under our modern system of sanitation, we discharge most of our sewage into the sea, throwing away with it an enormous quantity of nitrogen compounds, originally derived from the soil. It is evident that this process of robbing the soil of its nitrogen will render it ultimately incapable of supporting plant-life, and the food supply of humanity will be diminished.

In the early years of the present century, great regions in the American wheat area had become so exhausted that the cultivators were forced to seek fresh lands in Canada, and Mr. A. J. Balfour has suggested that the secret of the decline and fall of the Roman Empire is to be found in the decreasing productivity of the soil.

It is thus necessary to return to the soil the nitrogen of which it has been robbed, and there are three main sources of supply.

Ammonia is a by-product of gas manufacture. In 1913 the United Kingdom produced in this way from its gas works, iron works, coke ovens, &c., no less than 432,618 tons of ammonium sulphate. Again, in Chili and Peru there are vast deposits of naturally-formed nitrates which can be exported to countries in need of combined nitrogen for their land. These have been drawn upon very heavily. The figures during the war would be misleading, but for the ten years 1904—1913 inclusive, the total exports amounted to 20,850,000 tons. This demand is a steadily

increasing one, and it is evident that comparatively a short period may be given as sufficient to exhaust the available supplies.

There remains one other source of nitrogen, the atmosphere, and the chemical problem is how to convert this nitrogen into compounds which the vegetable world can use as nourishment. This is now actually being done on a very large scale. For the "fixation of atmospheric nitrogen" it is essential to employ energy in some form or other, and, since these compounds have to compete in price with the Chili nitrates, the power must be inexpensive. Water power, favourably situated, is the cheapest form of energy, and thus Norway has many advantages.

This Norwegian industry was set on foot by Professors Birkeland and Eyde, at Notodden, and in 1913 no less than 110,000 tons of nitrogenous material was synthesised by the Birkeland-Eyde works.

If air be heated strongly some of the nitrogen becomes combined with the oxygen present, the quantity depending upon the temperature. Thus at 2,675° six times as high a proportion is converted as at 1,811°, but to keep this proportion the mixture must be very rapidly cooled. If allowed to cool slowly the combination breaks up until the proportion present becomes only that arising from the then temperature.

The higher the temperature and the quicker the cooling the greater will be the percentage of combined nitrogen. In the Birkeland-Eyde process the air is blown through an electric arc, which is spread out by the aid of an electro-magnet into a disc of flame about six feet in diameter, thus allowing the passage of large quantities of air across the disc of flame to a cooling arrangement in which it is very rapidly deprived of its heat.

In another process the electric furnace is used to produce cyanamide, which is formed when lime and coke are heated in the presence of a stream of nitrogen. This substance comes on the market as a fertiliser under the name of nitrolim.

In a third process, described by A. K. Macbeth in the paper already referred to and due to Haber and Le Rossignol,

atmospheric nitrogen is combined with hydrogen to yield ammonia. The difficulty arising in this process is due to the dual action of heat upon the combination. At ordinary temperatures nitrogen has no affinity for hydrogen, while if the temperature is too high any ammonia formed is quickly decomposed. To meet this difficulty the inventors used a catalyst, which allowed of combination even at a comparatively low temperature under pressure.

By these various methods then the problem has been solved, and the nitrogen supply of the world rendered secure.

During the war there was a great advance in the actual production of nitrogen compounds by chemical methods. The necessity of a large supply of nitrogen compounds for the manufacture of explosives caused the expansion of the plant in use, and this will remain as a means of production for the manufacture of fertilisers, now that the demand for explosives has so greatly lessened.

With regard to the synthetic production of food materials themselves, it must be admitted that such production has hardly yet emerged from the experimental stage. The progress, however, which has been made in synthesising extremely complicated materials akin to the proteins has been very marked during the last decade. Even greater progress has been made in the present generation in the laboratory production of different sugars which occur in nature, such as glucose, cane-sugar, milk-sugar and fruits-sugar. The chemist is even synthesising certain sugars which do not occur naturally at all, though the possibility of their occurrence could be seen on theoretical grounds.

When we seek the origin of the power we use, we find that the greater part comes to us from the sun. Our coal is yielding up to us the heat stored up in it by the sun long ages ago. Our water powers are due to the present action of the sun's rays, and the only fuel not certainly owing its energy to the sun is mineral oil.

It seems possible that, during the volcanic age of the earth's history, certain carbides were produced by the combined heat

and pressure prevailing far below the surface level, and that, by reaction with water percolating through the strata, petroleum was formed, as acetylene is formed by the action of water on calcium carbide.

With the discovery of radio-activity a new reservoir of energy is opened, but at present we cannot direct or control the new force. The energy existing in the atom is so great that it represents a source of power, which if it could be tapped would eliminate all others from competition, and it may be regarded as probable that this will one day be accomplished. It is clear that the actual breaking up of the atom is in progress in the radio-active elements, but the process is extremely slow and at present practically beyond our power of direction or government.

It may be of interest to give one or two examples of the quantities of energy which are locked up in the radioactive elements. If we were able to obtain an ounce of radium in the pure state, we should find, according to measurements made with smaller quantities, that in the transformation described, it would liberate in an hour an amount of heat sufficient to raise rather more than an ounce of water from freezing-point to boiling-point, and this radiation would continue in lessening amount for countless years. Turning to uranium, it has been shown that in one pound of this metal there is a store of energy equivalent to that which is obtained from the combustion of rather over one hundred tons of coal. As to niton, a single cubic inch of this gas, if we could obtain it, would radiate energy equal to that emitted by a powerful arc lamp. To procure this cubic inch of niton, however, we should require no less than fifty pounds of radium ; and as at present the total quantity of the element which has so far been extracted from its ores amounts certainly to under an ounce, it is evident that we have still a long way to go before we reach the stage of practical utilisation. In the case of the slowly disintegrating elements like uranium, there is another factor in the problem—time—for these materials decom-

pose very sluggishly, so that uranium in one year only yields us 1-10,000,000,000 part of the total energy of transformation.

It will be necessary, if this great store is to be opened, that ordinary element some not (normally radioactive) should be used, as the available quantity of the radioactive elements is so small. If, or when, this power be placed in the hands of science its potentialities alike for good or evil will be quite unlimited. It is impossible to forecast the effect of such a discovery upon national or social existence.

It may be noted that radioactivity is almost entirely a Franco-British science. First came the work of Sir William Crookes, Sir J. J. Thomson, Becquerel, Debierne, and the Curies; then the great generalisations due to the labours of Sir Ernest Rutherford, Sir William Ramsay, Fleck, Moseley and Soddy. Germany has contributed nothing to this great advance in our knowledge.

NOTE.—A full account of radioactivity, written for the non-expert, will be found in Professor Soddy's *Interpretation of Radium.* In connection with problems of power the reader will find much of interest in *Matter and Energy,* by the same author (in the Home University Library). An account of the Periodic Law is to be found in Professor Letts' *Chemistry Old and New.*

4th February, 1921.

IN PHYSICS LECTURE THEATRE, QUEEN'S UNIVERSITY.

The President, PROFESSOR GREGG WILSON, in the Chair.

"THE PERCEPTION OF THE INVISIBLE."

(Illustrated by numerous Experiments).

By R. T. BEATTY, M.A., D.Sc.

Member of the Scientific Staff of the Admiralty. (by consent).

(*Abstract*).

The lecturer gave a brief review of the methods which men had evolved for transporting themselves and their property over the surface of the earth, and pointed out that while enormous machines had been developed for rapid transport by land, sea, and air, very little provision had been made for preventing disastrous collisions in darkness or fog, for detecting the presence of hostile war machines, or for communicating over distances greater than the eye could reach.

Even in so recent a period as that of the South African War, the horse and the heliograph (the latter requiring sunny weather for operation) were the only means of communication between rapidly moving troops when some miles apart. In general terms, the great mechanical revolution of the 19th century was not accompanied by a corresponding increase in the safety of human life.

New problems arose in 1914. Communication by wireless in many cases was found to be too public and too easily interfered with. On sea it was often necessary to signal in such a way as not to disclose the presence of the signalling ship. Methods of detection were required : detection of submarines, of approaching

aeroplanes, of enemy guns, of men moving at night. The lecturer next showed some remarkable experiments.

A method was shown of navigating a model ship so as to follow the course of a cable laid along the bottom of the sea. In this way a ship could safely make harbour in darkness or fog. The transmission of sound signals under water up to a distance of 50 miles was described, and its application explained to avoiding collisions at sea.

Other experiments demonstrated the presence of an invisible beam of light both by the fluorescent effects produced and by the production of a loud note in a telephone. The effect of interrupting the beam by the passage of a material body across it was strikingly shown.

Morse signals from such a beam could also be recorded on a moving band of paper.

A model of a lighthouse was exhibited in which the light was automatically switched on when darkness fell, and was extinguished by the rays of the rising sun.

Landscape photographs were shown, taken from an aeroplane, through clouds so thick as to prevent visual observations.

In conclusion, the lecturer remarked that work was going on unceasingly to increase safety in navigation of sea and air. The old enemies, darkness and fog, would always be with us, but their terrors were being rapidly diminished by scientific effort.

14th and 28th January, 11th and 25th February, 1921.

The President, PROFESSOR GREGG WILSON, in the Chair.

A COURSE OF FOUR LECTURES ON

SOME CHAPTERS IN MODERN BOTANY.

BY JAMES SMALL, D.SC., PH.C., F.L.S.,

Professor of Botany, Queen's University, Belfast.

IN BIOLOGICAL LECTURE THEATRE, QUEEN'S UNIVERSITY.

I.—THE WANDERINGS OF THE GROUNDSEL.

The Groundsel, *Senecio vulgaris*, is commonly regarded as only one species; that single species, however, includes a miscellaneous group of about one hundred microspecies, and for the purpose of this lecture the name "Groundsel" is extended beyond that familiar canary food to all its relatives which are included in the genus *Senecio*. Taking "Groundsel" as synonymous with *Senecio*, we deal, not with one species, but with about 2,500 species, ranging over all the habitable surface of the earth, and with a type which may be regarded as older than the Alps and Himalayas.

At a period which is variously estimated as from 4 millions to 40 millions of years ago none of the existing high mountain ranges were in existence. As the earth began to emerge from what is known as the Cretaceous Period, the western parts of South America were flat, and the region of the Amazons was covered, as it is to-day, by a very mixed, dense forest. The few herbaceous and semi-shrubby plants which grew in such forests were epiphytes or climbers, and amongst the semi-shrubby climbers were the ancestors of the groundsel. This ancestral type still lingers in the same region, as the genera *Siphocampylus*

and *Centropogon*, which are relatives of the little blue *Lobelia* of herbaceous borders and window-boxes.

About this time a great uplifting movement began which ultimately gave rise to the Andes and, later on, to the Rocky Mountains. This new range of mountains abutting on the tropical forests of the Amazons presented an entirely new habitat, which was open to colonisation by such of the forest species as could survive the change from a rich, warm, moist environment to the more or less arid conditions of the mountain side.

The Lobelioid climbers were amongst the early colonists; descending the trees, or rather failing to find trees upon which to climb, they first became scramblers on the low bushes of the forest edge. Then as they spread year by year up the hillside beyond the tree-limit to beyond the limit for bushes, they became ground-growing scramblers. The severe conditions reacted upon these pioneers, producing stunted growth and general crowding together of all parts of the plant. The stems being short, the leaves were crowded; the flower-stalks being short or altogether absent the flowers became crowded. The general tendencies towards the production of such characters as hairy appendages to the style branches, tails and apical appendages to the anthers, a few ovules or only one ovule in each ovary, etc., became expressed more fully in the flowers, and since these were already grouped in dense clusters, something very like the flower-head of a Composite was the result.

The young flowers being protected by the green leaves surrounding the flower-head, the calyx became useless, and disappeared at an early stage. The windy arid conditions on the hillside caused the development of hairs on most parts of the plants, and the hairs on the top of the young fruits grew longer than those lower down on the fruit. In this way there was formed the *pappus*, which proved very useful. The hairs, developed in response to the dry windy conditions, when organised as a fringe on the top of the fruit, became more than protective. They caught the wind, more or less like an expanded umbrella;

and because they did *not* form an unbroken surface they were much more effective than a purely sail-like mechanism.[1] These hairs, now called the pappus, made it possible for even a slight breeze to blow the light fruits to considerable distances.

The groundsel, therefore, may be said to have been originated by the uplifting of the Andes, and it proved eminently suited for the arid windy mountainous regions, where it still flourishes in great profusion. *Senecio* was, in fact, developed by the mountains with the mountains for the mountains. It arose by the modification of certain Amazonian Lobelioids towards the end of the Cretaceous Period, and started out on its many and long wanderings with an equipment of structure and constitution which was pre-eminently suited for mountaineering. As a natural consequence it usually took the "high" road in its travels.

Being spread by the wind both up and down the mountain slopes it reached to snow-level on the one hand and to the bush country around the forests on the other, and it naturally underwent corresponding changes. Near the snow-level it became even more densely compact and much more hairy, giving rise to the edelweiss and cudweed type. On the lower slopes, which were both warmer and more moist, the hairs of the pappus ceased to be developed as such and underwent various changes into awns and barbs which proved to be advantageous for dispersal by forest animals. Thus the groundsel gave rise to the bur-marigold and sunflower type. With these two South American progeny it then moved along the Andes southwards to Tierra del Fuego, and northwards to where the Rockies were beginning to appear in what are now the United States and Mexico.

On reaching the southern part of the Rockies *Senecio* developed, in part, long appendages to the style branches and became slightly modified in other ways, giving rise to the golden-rod and Michaelmas daisy type. By this time the Eocene Period

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[1] For details of this point and the general proofs (including the geological evidence and records of fossils), for the whole of this account see "The Origin and Development of Compositæ." Wesley. London, 1919.

was well-advanced and mountain ranges were beginning to appear in Asia and around the Mediterranean end of the Great Central Sea. The Yablonoi, Altai and Thian Shan ranges and the mountains of Afghanistan, Persia and Asia Minor formed one path stretching from close to the northern end of the Rockies to the Mediterranean region. While the Yablonoi, Khin gan, Sin-Ling and Himalayan ranges formed another similar path through China and Northern India to Asia Minor. Spurs from the latter path led through the Malay Peninsula and Sumatra to Australia, and also *via* the Philippines and New Guinea to the island continent.

Our wandering groundsel, showing its original liking for the "high" road, took both the main Asiatic paths, after coming north along the Rockies and crossing the Alaska-Siberian bridge. The wide, wet or frozen plains in the north were not congenial and these far-stretching paths were not colonized to any great extent, but the routes taken can still be traced by certain species. *Senecio altaicus*, for example, occurs along the first path from Siberia to Turkestan; *S. Ligularia* occurs along the second path.

The Mediterranean region, the next halting place, formed at this time the eastern end of the Great Central Sea which, by gradual draining and drying up in succeeding ages, formed at one end the semi-desert regions around Mesopotamia and Northern Africa, and at the other end the similarly arid Mexican plains. On reaching the warm woodlands, which at the end of the Eocene covered the many eastern islands of this primeval sea, our changeful groundsel in part again lost its pappus and by a few other slight changes developed the corn marigold type (*Chrysanthemum* and its allies chamomile and yarrow). Other colonies of groundsel in the same region about the same time developed by mutation a split down the back of the corolla, which with some slight accompanying changes gave rise to the lettuce and dandelion types.

The conditions in this early Mediterranean zone were so

different from those of the original home and of the paths of migration of the groundsel that, within the next geological period (Oligocene) still another set of changes took effect on the colonist giving rise to the elecampane and golden samphire type. This offshoot arose by an increase in the number of ray florets on account of the rich soil and favourable conditions for luxuriant growth; but very soon, geologically speaking, this same type developed into thistles by reason of the considerable drying up of the eastern end of the Great Central Sea and the resulting hot dry climate.

Meanwhile the descendants of the groundsel in its original home, multiplying, spreading and undergoing various slight changes in response to new and more favourable conditions, gave rise to other new types such as *Trixis* and *Gerbera* in Brazil. In the succeeding geological period (Miocene) the same Amazonian region was the scene of the origin of several still newer types, such as *Liabum*, *Vernonia* and hemp agrimony (*Eupatorium*). About the same time in Mexico the Michaelmas daisy type gave rise to the true daisy (*Bellis*) and some of the Mexican groundsels developed into the French marigold type (*Tagetes*), mainly as the result of the first stages in the drying-up of the western end of the Great Central Sea.

Before the Pliocene period was well begun an extensive migration took place southwards along the mountains of eastern Africa; not only the groundsels but the golden samphire and edelweiss types took part in this movement. South Africa was at this date beginning to become largely a semi-desert region, and such conditions had their inevitable effects on the last type, which originally came from near the zones of eternal snow on the Andes. In South Africa it gave rise to the "everlasting" type (*Helichrysum*). A little later on in the wooded regions which still occurred along the rivers, some of the groundsels lost their pappus and developed other means of dispersal, just as had happened before under such conditions in Brazil, Mexico and the Mediterranean. In South Africa this change was in some cases

accompanied by the sterilisation of the ovaries of the central florets of the flower-head ; and the products were first the South African marigold (*Ursinia*) and afterwards the ordinary marigold (*Calendula*).

Towards the end of the Pliocene period the wet, cold conditions obtaining on the northern plains of Asia yielded a belated derivative of the groundsel, the butter-bur and coltsfoot type, where the flowers are developed underground in the autumn and emerge only at blooming time in the spring.

An interesting case of convergent evolution occurred quite recently (Middle Pliocene, about a million years ago) in South Africa. There the colonists descended from the "everlasting" type on the one hand and from the golden samphire type on the other became so extremely alike that their progeny are classed together in the same small division of a tribe of the main Compositae family.

Perhaps the most remarkable point of all is this—the original groundsel type was equipped with such an adaptable constitution, such an efficient dispersal mechanism and such a strong vitality that it survives to the present day in all the regions to which it wandered. It flourishes amongst its numerous progeny, sparsely along some of the northern paths of migration, abundantly wherever conditions have been sufficiently favourable to allow of the development of that great number of individuals which often accompanies the origin of new types. Its 2,500 species exhibit every variety of herbaceous, shrubby and arboreal growth, but with this amazing range of vegetative form the structure of the flower-head and of the individual flowers remains constant even in microscopic details.

Such is the story of how the Groundsel wandered from its Andine home all over the surface of the earth, giving rise to numerous colonies, each of which developed its own peculiar characteristics, so that in time the highest and largest family of flowering plants, the Compositae with its 2,500 species, came into being. The story, here told very briefly and imperfectly,

is as worthy of an epic as the wanderings of Ulysses or the travels of Marco Polo; in fact, all the wanderings of primeval men are dwarfed into hurried events of recent and local interest in comparison with these journeys of the Groundsel in which about sixty million square miles were traversed in some forty million years.

Lantern slides were shown to illustrate climatic and topographical conditions, types of Compositae, details of structure and existing geographical distribution.

II.—THE ERECTNESS OF PLANTS.

The reader could scarcely follow the theories and experiments concerning the erectness of plants, which are expounded below, without some preliminary explanation of what protoplasm is conceived to be. Apart from the nucleus of each cell, the protoplast may be regarded as an emulsion consisting chiefly of :— 1. *carbohydrates*, such as sugars, starches, gums, mucilages, etc.; 2. *proteins*, which are nitrogenous compounds with some peculiar properties; 3. *enzymes*, which can be extracted from the cell, then dried and preserved as non-living substances for an indefinitely long time. The chemical composition and the physical structure of the third group of substances are still unknown, but it is known that they are closely associated in the cell with protein matter, and that they are not "alive."

Disregarding entirely the almost infinite variety of possible different combinations of nuclear material as chromosomes, and taking of the numerous kinds of carbohydrates, proteins and enzymes only two dozen of each group, the number of possible combinations of these three classes of substances with 24 varieties of each, is very much larger than the total number of species of living organisms that exist or have existed on the earth. With this suggested comparatively simple chemical composition for cytoplasm we can, therefore, consider that each species may have

its own peculiar protoplasm or cytoplasm, quite independent of the undoubted nuclear differences.

In connection with the erectness of plants, our attention must be directed more towards the proteins than towards the other classes. Proteins have the peculiar property of acting as bases or alkalies in an acidic medium and as acids in an alkaline medium. It is scarcely necessary to go into further detail as to how this occurs,[1] but this chemical behaviour of the proteins has important results. When a protein is dispersed in a fluid as emulsified particles, such particles carry an electric charge, which is positive in relatively acidic media and negative in relatively alkaline media. The proteins themselves are slightly acidic, and the medium need only be less acidic than the protein concerned to be *relatively* alkaline; while the medium must be more acidic than the protein itself to be *relatively* acidic. When the medium has an acidity about the same as that inherent in the protein, the protein particles act neither as a base nor as an acid, and they do not carry any electrical charge. This point or "zone" of acidity is called the isoelectric point of the protein.

The cytoplasm of the plant cell contains such protein[2] particles, which are lighter than the rest of the fluid. If these particles are large enough, e.g. 0·0002 mm. to 0·0008 mm. in radius, they will be acted upon by gravity to such an extent that they will "cream" upwards fairly rapidly, just as fat globules cream to the surface of milk. As calculated from Stokes' formula, the rate of creaming would be about 0·002 mm. to 0·028 mm. in seven minutes, which is the time taken in the case of a bean root for the action of gravity to develop its proper effect.

How the Root grows Down.

In the tip of every root there is a small group of cells which are full of protoplasm and are undergoing active cell-division.

[1] The reader will find this point and a number of related matters developed in my "Text Book of Botany." Churchill, London. 1921.

[2] Or more probably protein in loose combination with certain fatty substances such as lecithin.

Such a group of cells is called a *meristem.* Each cell in this group contains, according to this theory, protein particles which carry electro-positive charges because the rest of the cytoplasm in the root cells is relatively acidic. When the root is placed horizontally the particles, which are more or less uniformly distributed in the outer zones of cytoplasm, start to cream upwards. As these particles move upwards, and because they are positively charged, they develop a potential difference between the upper and the under sides of each cell. The greater number of positive charges proceed upwards, therefore the current, which is developed as a result of the potential difference, passes downwards.

Now each cell of the meristem is connected to its neighbours by very fine protoplasmic threads, and it is quite probable that the cells are by this means connected electrically in parallel and in series to form a battery. This battery, when the root is placed horizontally, gives quite a recognisable electric current, which passes downwards and along the cortex of the under side of the root (fig. 1). Then it passes around the root and returns

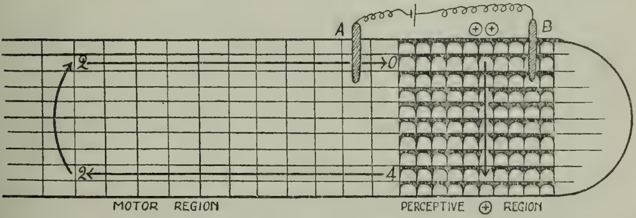

FIG. 1—Diagram of *root* apex to illustrate the *Hydrion Differentiation Theory* of geotropism. The "creaming" is indicated in the apical meristem (perceptive region). The arrows indicate the path of the "action current." A.B. Two electrodes used in measuring the changes in conductivity under geotropic stimulation.

along the upper side. The tissue has a very high electrical resistance ; for this reason and because there are numerous possibilities of leakage in the circuit, the current is stronger in

the under side than in the upper side of the root. The effect of the passage of an electric current through the normal plant cell is an increase of what is called permeability; this results in a decrease of turgor and a decrease in the rate of growth. The ultimate result in the root is that both the under and the upper sides grow at a slower rate than before, but the under side, being affected more, grows slower than the upper side, with the natural result that the root curves downwards.

The relationships between permeability, turgor and growth require to be clearly understood. The sap in the cavity within the cytoplasm of a mature plant cell acts like the gas in a balloon, and the cytoplasmic membrane acts like the skin or fabric of a balloon. If the balloon be well blown up it is more or less rigid or "turgid"; similarly with the cell. The sap or gas may be considered as always efficient in itself, but if the membrane be leaky (= permeable) then no amount of "blowing up" will make the cell or the balloon turgid. When the membrane in the cell is so altered that the molecules in solution in the sap can pass through (= permeate or leak) more easily than before, the cell loses a certain amount of its turgidity or *turgor*. The cell grows because its wall is always being stretched by the internal pressure (= osmotic pressure) of the sap. If the cytoplasmic membrane be leaky, the sap exerts less pressure, therefore each cell grows at a slower rate and the tissue, which is built up of many such cells, elongates less rapidly; it grows more slowly.

How the Stem grows Up.

The events which result in the turning-up of a stem, when it is placed horizontally, are very similar in kind to those previously described for the root. In the stem, however, the protein particles carry an electro-negative charge, because the rest of the cytoplasm is relatively alkaline. This difference has a very important effect on the direction of growth. The particles cream upwards as before, when the stem is placed horizontally, but since they are negatively charged the current which is developed flows

in the opposite direction to that which it takes in the root. The current flows from less negative to more negative points, and therefore flows upwards. It then passes along the upper side of the stem and returns along the under side (fig. 2), causing similar differences in permeability, turgor and rate of growth, but it is the *upper* side which is affected more. The under side, therefore, grows more rapidly than the upper side, and the stem curves upwards.

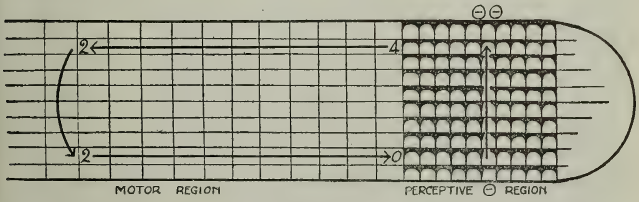

Fig. 2—Diagram of *stem* apex to illustrate the *Hydrion Differentiation Theory* of geotropism. The "creaming" is indicated in the apical meristem (perceptive region). The arrows indicate the path of the "action current."

Using this theory[1] as a working hypothesis, bean seedlings were grown under bell-jars in an atmosphere rendered slightly alkaline with ammonia vapour, with the result that the tips of the main roots turned slightly upwards, while the secondary roots or rootlets all grew upwards. Maize seedlings were treated in the same way and the young rootlets in that case also turned upwards.

The response of the stem was then tested by growing seedlings of Maize under bell-jars in an atmosphere rendered slightly acidic with the vapour of acetic acid, with the result that in almost every case the young shoot (enclosed in the epicotyl) turned downwards. In one experiment, a shoot which had curved downwards was taken out and grown in fresh air; then it recovered and slowly turned upwards. The experiment of reversal

[1] Published at some length in the New Phytologist, Vol. XIX., p. 49, 1920, and given briefly in my Textbook of Botany.

with acid was also done with sunflower seedlings, and marked downward curvatures were obtained with these also[1].

The Breathing of Plants as the Cause of their Erectness.

In the first lecture on the erectness of plants we considered how the root grows downwards because it is relatively acid, while the stem grows upwards because it is relatively alkaline. If this difference in the reaction of the two main parts of the plant is a fact, we should be able to find some general explanation of such a fundamental phenomenon.

The most generally occurring acidic substance in plants, which might vary in quantity, is carbon dioxide. All protoplasm in breathing gives off that gas, so that we have in respiration a process which yields sufficient carbon dioxide to make the cytoplasm relatively acidic. On the other hand the green parts of the plant, leaves and stems, in the presence of light use carbon dioxide in the building up of sugars and starches by the process called photosynthesis. This, of course, does not take place in roots. Stems, however, turn upwards in darkness, as well as in the presence of light, so there must be some other relevant difference between stem and root. If we examine the leaf or stem we find numerous large air-spaces amongst the cells, and these spaces communicate with the outer air through numerous small pores (*stomata*). If we examine the tip of the root, we find very much smaller air spaces amongst the cells, and these spaces do not communicate with the outer air directly but are connected with the comparatively distant air-spaces of the stem. Although the pores in the skin of the stem are small, they have been shown to be so efficient as gas-passages that 1·4 per cent. of the total surface in the form of numerous small openings lets through as much gas as would pass through half of the total surface in the form of one pore.

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[1] Photographic lantern slides of these results were shown.

The carbon dioxide of respiration, therefore, accumulates in the root apex, because in that region there is no photosynthesis and stomata (pores) do not occur in its outer layer. This acidic respiratory gàs, on the other hand, does not accumulate in the stem and leaves because in these organs it is either used up in photosynthesis or it diffuses through the stomata into the outer air. It is now clear that the carbon dioxide of respiration may be the substance which differentiates the root from the stem in so far as the relatively acidic or relatively alkaline reaction is concerned.

Using this extension of the theory as a working hypothesis, the stems of seedlings or young plants of many different species were induced to curve downwards. In the first experiments carried out by Miss M. W. Rea and the writer[1] the carbon dioxide was caused to accumulate in the stems and leaves by coating the whole of the green surface with vaseline and placing the plants in a dark box. The stomata were thus rendered useless and photosynthesis was stopped. The plants which showed downward curvature of the stem in these experiments included maize, garden geranium (*Pelargonium*), mouse-ear chickweed (*Cerastium*), sycamore seedlings, inflorescence of forget-me-not (*Myosotis*), seedlings of snapdragon (*Antirrhinum*), young plants of groundsel (*Senecio vulgaris*), and both flowering stems and leafy stems of marguerite (*Anthemis*).[2]

The effect of carbon dioxide has been further investigated by Miss M. J. Lynn, who finds that in an atmosphere containing about 30 per cent. of carbon dioxide reversal of the geotropic curvature of the stem invariably takes place within about one hour in the case of sunflower seedlings. This rapid curvature is probably due directly to turgor changes, not to actual growth changes which usually take much longer to appear.

At the beginning of this lecture your attention was directed to the two sets of sunflower seedlings in 30 per cent. carbon

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[1] See "The New Phytologist," Vol. XIX., p. 208. 1920.

[2] Photographic lantern slides of these results were shown.

dioxide and to the control set of seedlings in fresh air. All were placed horizontally; and now you can see for yourselves that in the control set all have turned upwards, while all the seedlings of both sets in carbon dioxide have turned downwards. These demonstration experiments were set up by Miss Lynn, and form conclusive proof of the reversing action of excess of carbon dioxide on geotropic curvature of the stem.[1]

It is interesting to note that the seedlings are able to recover when brought into fresh air, or when the carbon dioxide is removed. This occurs on practically every occasion when the seedlings are removed from the bell-jars at the conclusion of the reversing experiment.

Another Cause of Erectness in Plants.

Hitherto we have considered only gravity and its effects upon the plant whereby normally the root grows downwards and the stem upwards; but there is another stimulus which acts in nature. Roots turn away from light and stems turn towards light; so that the sunlight normally causes the stem to grow in an upward direction. It seemed probable that excess of carbon dioxide would also reverse this light-curvature in the stem[2]; and this phenomenon is being investigated by Miss I. Finnegan. The first experiments with sunflower seedlings yielded remarkable results. Miss Finnegan found that the stems not only curved *away* from the light, but they also curved downwards; so that both heliotropic and geotropic responses were reversed in the same plants. Further, these plants when removed to fresh air recovered first their normal geotropic response and then their normal heliotropic response, with the result that they formed a complete S curve, as shown on the screen.[3]

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[1] Further details are given in a forthcoming communication by Miss M. J. Lynn on this subject, which will probably appear in the New Phytologist, Vol. XX, No. 3, 1921.

[2] The theory of phototropism involved has been published in a brief form in the New Phytologist, Vol. XIX, p. 275, 1920; see also below p. 105.

[3] A series of photographic lantern slides of this experiment was shown.

HOW LEAVES AND BRANCHES ARE SPREAD OUT.

Everyone knows that in addition to the more or less erect main axis, stem and root, the plant also possesses stem-branches, leaves and rootlets, all of which project at various angles from the main axis.

Taking the root-system first, we have the meristem in the apex of the main root, the particles in some of the cells of which may be considered as always in the process of "creaming." This, in the vertical root (fig. 3, A), gives rise to what we may call a "normal polarity current," (that is a current produced by the apical meristem, which flows along the cortex, but being symmetrically arranged it produces no curvature). In the lateral root (fig. 3, B) a similar but smaller apical meristem produces an

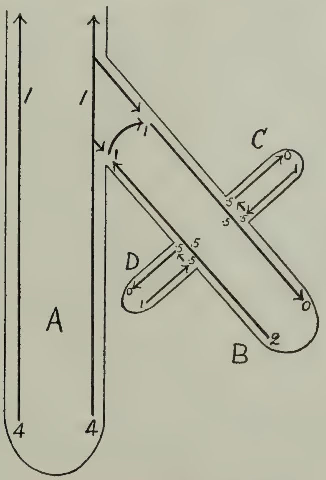

FIG. 3—Diagram of root system to illustrate the orientation of the secondary root, B, by the balancing effect on the action current, 2, 1, 1, 0, in it by the leak of normal polarity current from the main root, A, at the point 1.

"action current," because it is at an angle to the vertical. This action current flows upwards along the under side of the rootlet and back along the upper side. At the point where the rootlet, B, joins the main axis, A, we have therefore the possibility of a leakage of the current from the main root into the rootlet, towards the apex of the latter. This leaking current would tend to flow against the action current in the under side of the rootlet, and in the same direction as the action current in the upper side of the rootlet. The leaking current would, therefore, tend to augment the effects of the action current in the upper side and to diminish the effects in the under side of the rootlet, thus neutralising the unequal effects of the action current and preventing curvature.

The strength of the "action current" is known to vary directly as the sine of the angle with the vertical; its strength at the point of junction would obviously decrease the longer the rootlet (*i.e.*, the more distant the battery or apical meristem). The strength of the leak from the main root would vary similarly with the distance of the junction from the tip of the main root. The angle at which the leak just balances the unequal effects of the action current will be the only stable position for the lateral rootlet. This "angle of balance" will increase with any increase in length of the rootlet, because a stronger "action current" from the meristem, involving a larger angle will be required to give the same strength of current *at the junction* of root and rootlet. This angle will in the same way decrease with any increase in the distance of the junction from the main root apex, because the leaking current will then be weaker and the unequal effects of the action current in the rootlet will cause downward growth until the "leak" is again strong enough to neutralise the effect of the action current. In other words, the angle varies directly as L (= length of lateral rootlet) and inversely as D (= distance of junction from main apex). Since the strength of the action current varies directly as the sine of the angle, the fraction $\frac{L}{D}$ should vary as the sine of the angle, unless other

factors are also acting. The same explanation may be applied to the angles of stem-branches and of leaves.

This extension of the theory was taken up by Miss Lynn and the writer[1]. The angles, lengths and distances were measured in various plants. The results for root branches of the pea, and for the stem branches of privet, cherry laurel, dock, yellow cress and horse-tails were found to be in accordance with the theory, when an allowance of 10° on either side of the theoretical angle was made. Considering that many other as yet unanalysed factors may act in the growth of such branches, a deviation of ten degrees in either direction is quite a moderate "experimental error" on the part of the geotropic orientating mechanism. The data for leaves were not so satisfactory, and the regular action of other factors was indicated. This was explained when Dr. Harold Wager informed us that from some unknown cause[2] young leaves grow more on their under sides and old leaves grow more on their upper sides. When these interfering effects are eliminated by taking the angle as 90° less the angle of the leaf with the vertical, the data for leaves are in as complete accord with the theory of the angle of balance as are those for stem and root-branches.

Leaves and the branches of stems and roots may, therefore, be said to be spread out primarily by the balancing action which the leakage from the main stem has upon the effects of the action currents in the lateral organs.

How Leaves Originate.

Up to the present there has been no detailed theory for the origin of leaves but, with the new insight into what is occurring in the stem apex, it should be possible to obtain some idea of how leaves happen to develop at the apex of the stem. The following

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[1] See the "New Phytologist," Vol. XIX, p. 209. 1920.

[2] This cause very probably is the effect of light on photosynthesis and the carbon dioxide balance in upper and lower sides of the leaf.

suggestions have been put forward tentatively[1], as a working hypothesis which may open up this particular field to experimental investigations.

Any apical meristem is considered as generating an electric current. The apical meristem of the stem produces a symmetrically flowing "normal polarity current" as previously described. The primordial knob which develops into a leaf starts as a slight more or less hemispherical swelling near the stem apex; then it develops a meristematic region and grows out to form a leaf. The young leaves developed in this way overlap the comparatively small apex of the main axis of the stem.

The electric fields of the currents produced by the growing points (meristems) of the leaves and of the stem may be compared with the magnetic fields of magnets. The electric field of the stem current is small, compared with that of the larger leaf current. The stem is represented by a small cylindrical magnet placed vertically, and the leaf is represented by the opposite pole of a large bar magnet placed horizontally. If the combined magnetic fields are investigated by means of iron filings, when the large magnet is set close to the top (opposite pole) of the smaller magnet, a small neutral area will be found to be induced on the side of the "axis" opposite to the large magnet.

Now, if normal polarity of growth is due to the normal polarity current, the cells in this neutral area will be freed from that influence and will grow in all directions. Such growth would give rise to the first stage of the leaf as a primordial knob. When growth advanced further and a meristem developed, an electric current and its electric field would result. Meanwhile the first leaf would be carried away from the stem apex by the elongation of the stem, and the new leaf (originated by the effect of the electric field of the first leaf on the normal polarity current at the stem apex) would be left to help in the development of the primordial knob of a third leaf, and so on.

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[1] New Phytologist, Vol. XIX, p. 210. 1920.

An interesting case is that of opposite pairs of leaves, which may be imitated with two large horizontal bar magnets placed very close to the top of a small vertical cylindrical magnet, as shown in the demonstration experiment on the table. In this case the mutual effect of the two equal large fields and the smaller field is the production of two equal small neutral areas at right angles to the bar magnets. These areas in the plant would become primordial knobs at the stem apex, and a pair of leaves at right angles to the first pair would result. This is a very common case in the Dicotyledons, but very rare amongst the Monocotyledons, and the first pair of leaves may be taken as the seed-leaves or cotyledons.

Some Practical Applications.

The great outstanding practical application of these purely scientific facts and theories occurs in the "earthing-up" of potatoes. The potato tuber is a stem structure, a swelling at the end of a lateral branch which is induced to grow downwards in the soil by covering the main stem with earth above the level of the buds in the axils of the lower leaves. When the stem is covered with earth the stomata cannot act efficiently as passages for the respiratory carbon dioxide, and that gas is not used up in photosynthesis because of the absence of light. The farmer and the gardener, therefore, have been carrying on this particular experimental reversal of geotropic curvature in the stem every year in the "earthing-up" of their potatoes.

A minority opinion in the past has been expressed against "earthing-up" as a method of increasing the production of tubers, but with the new scientific basis for this process there can be no doubt that, within certain limits, more earthing-up means more potatoes. Enough green foliage must be left above ground to produce the starch for filling the tubers ; but in Forfarshire, at any rate, those farmers who earth-up their potatoes, not only once but twice or more, get the heavier crops. A comparatively small amount of foliage seems to be sufficient to produce all the starch that is required.

Apart from this very extensive and important economic application of the effect of carbon dioxide on the direction of growth, there are numerous other lines of scientific and economic investigation in which the fact that the root is relatively acid while the stem is relatively alkaline, has been overlooked. The new evidence for the verity of this phenomena may prove of great value in directing the attention of investigators to its obvious results in experimental and observational work.

For example, it is well known that only a few plants are able to grow in distinctly acid media, such as sphagnum bogs and sphagnum peat; similarly a few other plants show a very decided preference for chalky soils. The continued existence of both classes obviously depends upon special relations between the reaction of the soil and the reaction of the roots of the plants.

Two interesting cases of the influence of "reaction" on the growth of the plant occur in the maize and the bean. The ordinary maize is yellow, but varieties are sold which are white, *e.g.*, Sutton's White Horse-tooth Maize. The colour is due to a substance which becomes intensely yellow with ammonia vapour and is changed to a colourless product by acids. The yellow maize is yellow because it is, as a whole, relatively alkaline; while the white maize is white because it is in the same way relatively acid. Keeping in mind that the root is acid, it is interesting to note that, while in yellow maize the main root aborts when it is not more than two millimetres long, the white (acidic) maize produces a main root several inches long.

A similar phenomen occurs in the bean. Broad beans with green seed-coats give straighter longer main roots on first germinating than do those with brown seed-coats. Such seedlings as the former naturally stand a better chance of successful growth into mature plants. Now, the green bean is acid and the brown bean is relatively alkaline. The colouring matter can be extracted; it is green in acids but turns brown in alkaline media.

A FURTHER EXTENSION OF THE THEORY.

An obvious corollary to the theory as outlined above is that the sign of the electric charge on the particles which form the outermost layer of the cytoplasm depends upon the concentration of acids near that membrane. Not only the sign but also the *density*[1] of the charge (*i.e.*, the degree of polarisation or electrification) will be affected by the varying amounts of acid or alkali present. This corollary forms the basis of the theory of heliotropism outlined above (p. 98). Since the density of the charge on the membrane largely governs the degree of permeability and, therefore, of turgor and growth, it has very important bearings also upon the influence of the acidity or alkalinity of the medium upon disinfection, plant diseases, infection of plants or animals by fungi or bacteria, the cultivation of bacteria, the long recognised effects of acids and alkalies upon both plants and animals and upon protoplasm in general. The concentration of carbon dioxide governs not only the erectness of plants but also very probably their resistance or susceptibility to disease, their rate of growth, their storage of starch and a multitude of other phenomena in the details of the "living" of these organisms.

EXPLANATION OF PLATES.

PLATE I.

V.—*Coated with vaseline.* UV.—*Unvaselined.*

FIG. 1.—Bean seedling showing retardation of growth in the dark with seedlings vaselined (V.) as compared with others left unvaselined (U.V.).

FIG. 2.—Maize seedlings showing reversal of gravity curvature in one (V.), and recovery from this effect in another (V[1].), after being vaselined and kept in the dark for several days.

FIG. 3.—Vaselined maize seedlings several days after being placed horizontally in the dark. Three show downward curvature, three are erect, and four or five are nearly horizontal.

FIG. 4.—Vaselined maize seedlings after similar treatment; the one which is curved down recovered on being placed in sunlight.

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[1] See my "Text Book of Botany," foot-note, pp. 353-4.

FIG. 5.—*Antirrhinum* seedlings after treatment. The control (U.V.) curved up. The lowest vaselined plant turned up at first and then curved downwards.

FIG. 6.—Ivy-leaved *Pelargonium* after treatment. In the control (U.V.) the stem and young leaves curved up. In one of the vaselined plants (V^{11}.) both young leaves and the stem curved downwards.

FIG. 7.—Two stems of the same species showing downward curves after treatment.

FIG. 8.—Stem apex of the plant in figure 6 ($V.^{11}$). Experiments by Miss M. W. Rea.

PLATE II.

FIG. 9.—Seedling of *Cerastium* after treatment. The control (U.V.) was an older plant. The lower two vaselined plants show downward curves. Photographed in the erect position in order to show the turgidity of the curves.

FIG. 10.—A similar plant after treatment. Photographed erect.

FIGS. 11-14.—Reversal of gravity-curvature in sunflower seedlings placed in 13 to 16 per cent. carbon dioxide and recovery of normal curvature. Experiments by Miss M. J. Lynn.

FIG. 11.—Reversed curvature of six seedling stems in carbon dioxide.

FIG. 12.—Recovered normal curvature in the same seedlings after the carbon dioxide had been removed.

FIG. 13.—Reversed curvature in eight out of nine seedling stems in carbon dioxide.

FIG. 14.—Recovered normal curvature in the same seedlings after removal from the jar into fresh air.

PLATE III.

FIG. 15.—One plant of *Anthemis* sp. with one branch vaselined and showing reversed curvature, the other unvaselined showing normal curvature and elongation. Experiment by Miss M. W. Rea.

FIGS. 16-20.—Reversal of gravity curves and light curves in carbon dioxide, and recovery of both normal curvatures. Experiment by Miss I. Finnegan.

FIG. 16.—Sunflower seedlings in carbon dioxide growing *away* from light and *downwards.*

FIG. 17.—The same plants after removal to fresh air, showing recovery of normal response to gravity in one seedling.

FIG. 18.—The same a day later, showing recovery of normal gravity-curvature in both seedlings.

FIG. 19.—The same a few more days later, showing recovery of normal light-curvature in both seedlings.

FIG. 20.—The same still later. *a* to *b* reversed heliotropism ; *b* to *c* reversed geotropism ; *c* to *d* recovered normal geotropism ; *d* to *e* recovered normal heliotropism. In one seedling the recovered light-curve is in the new growth (*d* to *e*); in the other it is in the older part of the stem (d^1 to e^1).

Plate I.

FIG. 1

FIG. 2

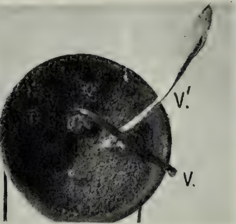

FIG. 3

FIG. 4

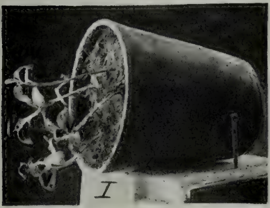

FIG. 5

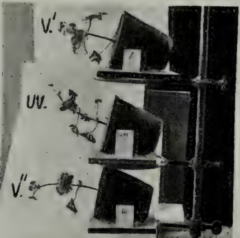

FIG. 6

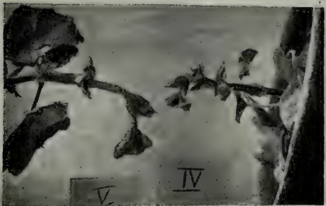

FIG. 7

FIG. 8

PLATE II.

FIG. 9

FIG. 10

FIG. 11

FIG. 12

FIG. 13

FIG. 14

Plate III

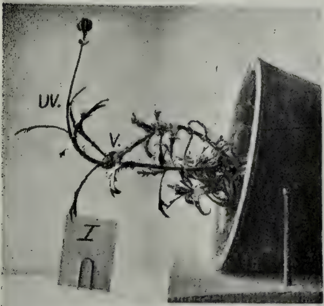

FIG. 15

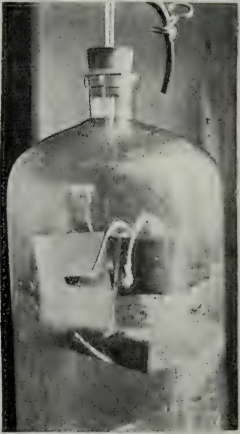

FIG. 16

FIG. 17

FIG. 18

FIG. 19

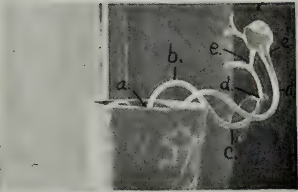

FIG. 20

BELFAST
NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.

PROCEEDINGS,

100TH SESSION 1920-1921.

No. 3.

8TH MARCH, 1921.

DR. THOMAS ANDREWS:
THE GREAT CHEMIST AND PHYSICIST.

BY HENRY RIDDELL, M.E., M.I.MECH.E.

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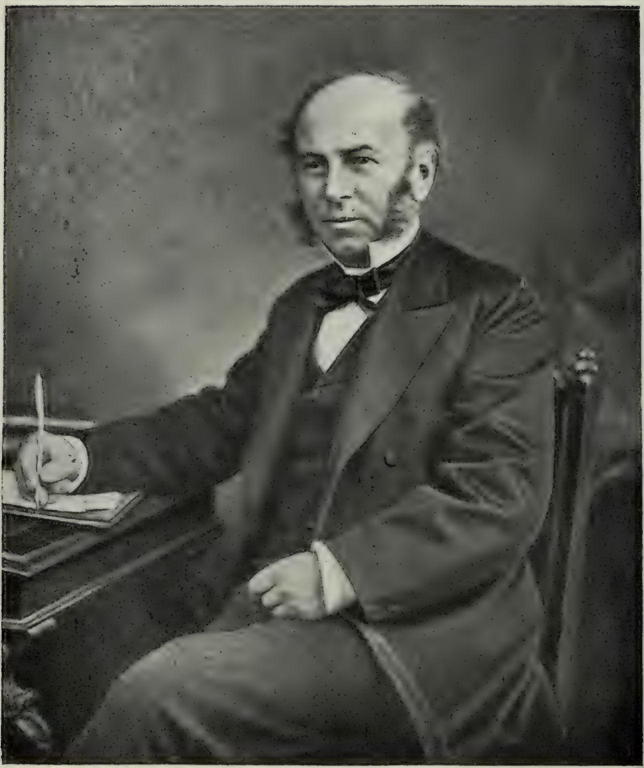


THOMAS ANDREWS, M.D., M.R.I.A.

From a Photograph presented to the Society by Mrs. Andrews in 1888.

8th March, 1921.

In Chemical Lecture Theatre, Queen's University.

The President, Professor Gregg Wilson, in the Chair.

Dr. THOMAS ANDREWS: THE GREAT CHEMIST AND PHYSICIST,

By Henry Riddell, M.E., M.I.M.E
Hon. Treasurer of Society.

(*Abstract.*)

[Some apparatus used by Dr. Andrews for his famous experiments were on exhibition in the lecture room.]

It is right at times for the people of a nation, the citizens of any town, and the members of a Society like ours, to look back upon their history and bethink themselves of the men who have gone before them, to use as the text for their meditations those words from Ecclesiasticus, "Let us praise famous men and the fathers who begot us." And there is no time more suitable to us for such a purpose than this, the Centenary Year of our Society, and so the Council have arranged to publish a memorial volume, in which will be found complete lists of our members, with short biographies of the best known men, and a statement of the great work they have done for their generation and for the world. And we have a right to be proud of such men, for example, as John Templeton, William Thomson, Robert Patterson, Wyville Thomson, R. O. Cunningham and others in the study of Natural History, John Purser, Peter Guthrie Tait, James Thomson and Joseph D. Everett, in the realms of Physical and Mathematical Science, while the name of Thomas Andrews stands out upon our roll, the great investigator in Chemical Physics.

It is therefore at the request of the Council of the Society that I have this evening to give you an account, necessarily imperfect, of Dr. Andrews and his work. There are many reasons for our interest in Andrews. He was a fellow townsman, a prominent and greatly respected member of our Society, of which he was President 1854—1856, and a scientific investigator whose name and work are known wherever Science is esteemed. To me he was the valued and venerated teacher for whom I had unbounded admiration and affection. And not least upon our list, by his kind and generous heart, his care for the feelings and interest of others, and his sincere and upright life, he earned the grand title of an honourable and Christian gentleman.

Thomas Andrews was born on 19th December, 1813, at 3 Donegall Square South, and lived there as a boy and as a man until his transfer to the building erected for him in this College grounds in 1845. In those days the square around the Old Linen Hall was almost wholly residential. Next door to the Andrews family for years dwelt Mr. Bristow, a well-known solicitor of the town, the Bristow name being still familiar in Belfast and on the roll of our Society. Other residents there were Charles Lanyon, the Architect of this College, and a member of our Society, John Workman, whose descendants to the third and fourth generation are now among our members, and John Sinclair, of the firm of J. & T. Sinclair, a name best remembered among us in the person of the late Right Hon. Thomas Sinclair, a distinguished Graduate of this College and a man much loved and respected in the City of Belfast.

The Andrews family, then as now, were closely connected with the mercantile life of the town, and are to-day represented by the Flax Spinners of Comber and the Flour Millers of Belfast, while the name of Michael Andrews, of Ardoyne, is ever famous in the history of the Linen Trade, in which the family is still concerned. Thomas Andrews' grandfather, Michael Andrews, was the eldest son of John Andrews of Comber, and his father, also Thomas, was in business in Belfast as a linen merchant,

having his office in Thompson's Court, off Donegall Street, while Michael Andrews, of Ardoyne, had his residence at 72 Donegall Street and his office in York Lane. The boy Thomas was sent to school first to the old Belfast Academy in Donegall Street, but was soon transferred to the Academical Institution, in which from 1835 to 1845 he was to be the Professor of Chemistry in its Collegiate department. He did much of his important work while in this post, and before he left it in 1845 to join the organizing staff of the projected Queen's College, or rather the Northern College as it was first called, his name was known over all Europe. He was a diligent pupil, paying especial attention to French and having a liking for Chemistry. He left school before he was fifteen to join his father's business, but his heart was not in the work and discussions took place regarding his future. A family friend at that time was Doctor James McDonnell, who was a man of mark and influence in Belfast. He belonged to the famous Antrim family, and was educated by that remarkable teacher David Manson, graduated in Edinburgh in 1784 at the age of twenty-two, and started practice in Belfast, where he soon became one of the leading Physicians. He was the originator of the old Belfast Literary Society and one of the founders of the Linen Hall Library. He was greatly esteemed by our Society, and belonging to it there is a fine bust of the Doctor, still among our collection of pictures, books and manuscripts, a collection which is exceedingly valuable and ought to be available for study in any New Museum to be erected by the City. His graduation thesis was on the treatment of those apparently drowned and he was bold enough to suggest the transfusion of blood as a last resort. Between this man and the school-boy fifty years younger a curious companionship arose more like that between equals in age and acquirements than between persons so different in years. He advised that the youth should be educated for the medical profession, taking care in the course of this education that the subjects studied should be such as would be of service to him, if later on his duty or inclination should call him to commercial life.

Andrews then was sent to Glasgow to study Chemistry under Dr. Thomas Thomson, who had established there the first school of Practical Chemistry in Great Britain. In Glasgow Andrews worked hard, and received at the end of the session certificates of diligence and ability in both Chemistry and Natural Philosophy. It was this year that was published his first scientific paper, from a boy of fifteen, in the Phil. Magazine, the subject being certain peculiarities of the blow-pipe flame.

He did not seem satisfied with his outlook at Glasgow and it was later arranged that next year he should go to Paris to try entering one of the laboratories there, to get a wider view of his favourite study. It was in this year, 1830, that appeared his first paper on a truly Chemical Subject, "The Separation of Baryta or Strontia when in Union with Lime," a paper which gave promise of the care for detail and accuracy which was always characteristic of his work. In the Autumn of 1830 Andrews sailed from Dublin for Bordeaux with some letters of introduction, intending to make a somewhat extended tour before reaching Paris, where he had determined to study. It was a bold step for a boy not yet seventeen. France was just emerging from the revolution which had placed Louis Phillippe on the throne as a constitutional Monarch, and the effects were so feared that travellers were few, there being only twelve on the boat in which he sailed. By a singular piece of good fortune his diary of this trip has survived the ninety years, and you will forgive me, I hope, if I quote some passages to show the power of thought and expression rare in a boy so young. He describes his journey up the river to Bordeaux—"On leaving Poliac (where the Customs Officers had boarded the ship), the banks of the river present a lively and picturesque appearance. Vines, with occasional meadows are the only crops cultivated. Approaching Bordeaux the view gains in richness and variety. Country villas surrounded by clusters of trees appear, and on passing the mound, the shipping and the town burst suddenly into view. The appearance of the town is rather engaging. It is built of a coarse siliceous sandstone

which is obtained from the right bank of the river. Some of the buildings, such as the Theatre, are in the highest state of external beauty, and there is a very extensive *Place* in which some rows of trees are planted." He describes the company in his hotel, "where politics were discussed with the utmost eagerness." "At the table d'hote where I dined was a lady who had arrived from Paris wearing a tri-coloured ribbon. She took the lead in every conversation, was, in fact, the orator of the party. Nothing can exceed the interest the French have taken in their Revolution. They can speak of nothing else. If the conversation passes for a moment to any other subject of local or personal interest, it soon returns to the detail of the events in Paris. The same actions are related over and over again, and followed by the same exclamations of wonder and delight. Every article in the constitution is received with a unanimous and cordial assent. *C'est bien cela! C'est bien cela!* is repeated after every clause and re-echoed by every voice. There is no diversity of opinion on any point. Had each individual framed a code himself he could not have been better satisfied with it. Such are the French people. Scarce half a century ago they submitted without a murmur to the most despotic of governments and tyrannical of priesthoods. They admired their Government; they adored their King; they loved their Church. Suddenly a wonderful revolution took place in their government and in their religion, and they regarded with equal veneration the new idol they had set up. It, in turn, soon passed away—a reign of confusion and terror succeeded, till a military despot seized the reins of the Kingdom. The nation bowed before his feet, and, dazzled by the splendour of his victories, regarded him in the light of a God. A foreign force drove the usurper from the external throne in France, but he still retained his dominion over their hearts. This dynasty has now been expelled—for ever? The nation has had its own election and what has been its choice? Not its much vaunted Republic, nor still less its military despotism. It has formed a limited Monarchy such as that of England, but

it has abolished an established Church and retained the Monarch in faster bonds. Its new Constitution is looked upon as a *chef d'œuvre* of perfection, as forming a guarantee against every danger, as ensuring to them an ever during liberty. May they enjoy it as they deserve it. Their laws are good but will they be fulfilled? Were a second Buonaparte to arrive, could he not, taking advantage of the natural vivacity of the nation, trample on their newly acquired rights and set up a new subject for their admiration?" I am inclined to think you will agree that a boy of sixteen shows here a graphic power of expression and an insight far beyond his years. Continuing his tour he passed through the mountainous Auvergne region, giving close study to the geological formations and collecting specimens which he catalogues and names. As showing the terms of the friendship between him and Dr. McDonnell I shall quote one or two letters of the Doctor's which have survived till to-day. The good Doctor had been studying many subjects in which he was interested and refers to experiments in which Andrews had shared. He had been investigating the proportion of CO_2 in atmospheric air, and had been taking samples upon the hills round Belfast. He had been studying the geology of County Antrim and County Down, and experimenting on the effect of altitude on the pulse and respiration. We find him putting a number of geological questions to Andrews on his journey through Auvergne, and he goes on—"I much wish to know whether Chemistry furnishes any plain or simple criterion by which to distinguish Trapps from all other rocks except Lava, and again another difference between Lava and Trapp? Is there any chalk or Lias or Mulatto in Auvergne? and, if dykes cutting them, change the lime into marble or render it phosphorescent? Any red flints or gypsum? and how situated with regard to the Trapp? Whether the Trapp lies horizontal or vertical?—Is the outline of the mountains like or unlike ours?" In another letter, sent by the hand of a friend, he opens very characteristically "My dear Thomas, finding that this costs me nothing I must write, though I have nothing of moment to say."

He repeats his question as to the chemical distinction between Trapp and other rocks, making the interesting point, that, for want of such a criterion he finds Playfair and Allan placing the Portrush Ammonites as being found in Siliceous slates while Dr. Richardson and hundreds of others called it Siliceous Trapp or Basalt. He gives him numerous commissions to haunt the bookstalls looking for volumes which are wanting in certain series in the Doctor's library, and we form an idea of the amazing variety of the literary and scientific interests of McDonnell. He finishes by discoursing upon the effect of altitude on the heart and the rate of respiration and urges Andrews if ever he should gain access to Gay Lussac, to ask him to describe his sensations during his famous balloon ascent of 22,000 feet. I cannot take time to quote further from this most interesting correspondence, but we must wonder greatly when we think it is addressed to a boy wanting some months of seventeen.

After his arrival in Paris Andrews presented his letters, and was very kindly received by some of the great scientists then in the city. It was vacation time and none of the regular schools were open, but he entered some classes specially intended for students remaining in Paris at such a season, and congratulated himself that he was using his time to so much advantage. He ultimately succeeded in gaining admission to the laboratory of M. Dumas, and ever after retained the friendship of this great man. Unfortunately a severe illness compelled him to leave France earlier than he had intended, and on his return to Ireland he entered Dublin as a medical student. While there he continued his great interest in Chemistry and laboured diligently in his preparation for his profession. During his student days he published a remarkable paper on the "Chemical Changes in the blood of Cholera patients," gaining his material during the great epidemic which broke over Belfast in 1832. He completed his medical course in Edinburgh where he took his degree, obtaining the diploma of the Royal College of Surgeons in April, 1835, and his M.D. in the August of the same year. It was immediately

after obtaining his degree that he joined our society, on the register of which for 1835 he appears as Thomas Andrews, M.D. He was not yet twenty-two years old, but had been already offered the position of Chemistry professor by both the great Dublin schools of medicine. He was not long in Belfast before he was appointed the first professor of Chemistry in the newly established Medical College in the Academical Institution, which teaching he combined with a growing private practice, and in spite of the claims of both upon his time, managed, as I have already said, to do much splendid work. It is almost forgotten now that there ever was such a collegiate department in the Institution, as it was closed when the Queen's College was opened in 1849. The year after his appointment in Belfast he spent a vacation in Paris, renewing his acquaintance with M. Dumas, and making that of M. Chevreul, M. Berthier, and M. Gay Lussac. In this visit he had much pleasure in the company of the great physicist Thomas Graham, and the latter was the means of introducing Andrews to the notice of many of the men who made Paris of the day so famous. To Graham he owed also his introduction to Faraday, beginning a very close friendship which ended only with Faraday's death. Andrews had even thus early begun his series of experiments on the electrical relations of elements and compounds, and took the opportunity of this visit to purchase some of the latest and most accurate instruments. Recognition soon came to him. In 1839 he was elected a Member of the Royal Irish Academy, and he was one of the original members of the Chemical Society in 1841. It was in 1842 that he married, his wife being a grand-daughter of Adam Johnston of Glynn, who was Andrews' own great grandfather. I am glad to remind you that among our members the family of my old master is still well represented, and we all know Miss E. Andrews as an active investigator into the antiquities and folk lore of our Province.

Andrews received the Royal Medal in 1844 for one of his investigations upon the heat developed in chemical combination. In 1845 he was invited to offer himself for the vacant chair of

Chemistry in King's College, London, but declined. The new Colleges in Ireland were about to be launched, and it was clear that Andrews was the man marked out as necessary, and this same year he was appointed Vice-President in order that by his knowledge and common sense he should help to direct the course and arrange the details of the new scheme. When the time arrived for the appointment to the professorships, Andrews naturally received that of Chemistry. In 1849, the birth year of the University, he was elected to a Fellowship of the Royal Society, and it was in this year began that period of earnest and inspiring teaching which so many of his old pupils remember with gratitude and admiration. From this time his life flowed on, devoted to his students and his researches. I need offer no proofs of the estimation in which Andrews was held all over the world. Many degrees and honours were showered upon him; the thirty years passed rapidly by and the burden of approaching old age began to be felt, so that in 1879 he resigned and for six years lived in retirement in Fortwilliam Park until his death in 1885. Perhaps this is the time to say something of my own memories of the great teacher. I was much past ordinary student age when I entered the Engineering School, having already completed two technical apprenticeships. Before I entered Queen's College I had twice listened to Andrews lecturing to the members of this society. The first lecture was fifty-one years ago upon his own great work on the continuity of the liquid and gaseous state, and was a revelation of the extreme clearness of expression and power of forcing an audience to be interested and eager to hear what he was saying. I remember a remark made by the then President of the society, Joseph John Murphy, of which I shall speak when explaining this great research. The second lecture was a beautifully illustrated and clear discourse on the then recently invented Gramme ring, and its uses in electro-generating machinery. It drove me to study Faraday, for which I am for ever grateful. It followed therefore that I had some idea of the man I was going to learn from, but I had not formed the full

knowledge of his kind heart or of his eagerness to help a willing student. It was his habit, after every lecture, to remain for a short time at the table to answer any questions students might come to ask him, and I always took advantage of this opportunity. In my time his lectures were models of what was needed. Thorough, in that they dealt with every essential, but not redundant, beautifully clear and illustrated with well chosen experiments always thoroughly prepared and always successful. He suffered somewhat from the kindness of his heart in that he was never able to show that outward sternness which is so needful to keep discipline in a class of youths. There was in my time no general teaching of Practical Chemistry. The accommodation for laboratory work was so scanty that it was necessary to select the few pupils by examination, there being also a possibility of obtaining admission by payment of a heavy fee, which I do not remember to have been much availed of. In this laboratory work I learned to know Andrews thoroughly and to have a great regard and affection for him. He never spent more than a few minutes at a time in our laboratory, but it was the frequent visits which I was allowed to make to his own room in which lay the charm and the delight of my time there. He used often to call me up to help him to set up some piece of apparatus, and I have always been sure he never needed the assistance he called for, that it was his plan to help a man he knew to be anxious to learn. I had many interesting and enlightening conversations with him. I remember on one occasion a whole morning spent in his room discussing his work and some chemical problems. I asked him if he accepted the idea that all elements had atomic weights with simple numerical relation to that of Hydrogen. He said that this could not be unreservedly accepted, as accurate determinations did not support it. At the same time he thought there was evidence that some intimate connection existed. "We physicists," he said, I quote the word as illustrating his position, "We physicists look to the future to show that all the elements are built up from the same primordial

substance, matter or otherwise." He thought that the atomic weights might not represent an exact measure of this primordial substance, but only some ratio to it, constant for each element. That they might be affected by the interference of some form of energy. These were only speculations and must be left to the future to prove or disprove. He thought it possible that all chemical action was dependent on electrical forces, but in what way he saw no method of discovering. Of course all his answers were coloured by the nature of my questions, and he smilingly assured me that these odd speculations did not form any hypothesis which he could use in lecturing. I sometimes wonder what the Doctor would have thought of the modern theories which have been so rapidly developed in Physical Chemistry, the present conception of the atom and the molecule, the almost certain knowledge that several editions of the same element may be found, alike in chemical actions but differing in atomic weights, and the suggestion that the known figures are but means between these differing varieties.

Dr. Andrews told me that, from his point of view, he saw no reason to say that transmutation of the elements was impossible; its difficulty must be measured by the constant failure of all attempts. If ever it be found possible to realize the aim of the old alchemists by manufacturing gold he had the idea that it would be too costly for use. I should like to have him watch the transformation of the Radium relatives and to see his own researches followed up, to the extent they have reached to-day. We ought not to forget that Pneumatic Chemistry had its origin in Britain and that the greatest advances had been made there. Faraday began an enquiry which Andrews continued, and in which he may be said to have determined the laws. In later years Rayleigh, Ramsey and others have made advances almost incredible in amount in the discovery of new gaseous elements, and we are proud to remember that the main work in this branch of Physical Chemistry has been done by our fellow countrymen.

On Andrews' retirement in 1879, his fellow townsmen

honoured him by instituting the Andrews Studentship in Chemistry, and by presenting his portrait to the University, where it hangs in the Examination Hall. At his death he was mourned as a great teacher and as a good and kindly man, for whose life his country was grateful, and for his death sorrowed deeply.

It is impossible to deal at all fully with his many investigations and I shall only mention a few.

In 1841 he began to publish a great series of researches on the heat developed in chemical combination, and it may be remembered that in 1840 Hess published the results of a number of experiments on the same subject. It is singular how often we find a series of investigations proceeding in one country, and at the same time, quite independently, somewhere far away another man has chosen to follow the same research, and publication is almost simultaneous. Andrews' experiments were perhaps more accurate in results and more numerous than those of Hess, but both deserve honour for their work. It was a favourite subject with Andrews, and he continued to work occasionally on it for many years, while for the time between 1841 and 1849 it formed almost his only research. It is characteristic of the man that he best loved to seek the inner secrets of a chemical law from the point of view of energy, and it is interesting to note that all through the great series of experiments he seems to take for granted the law of conservation of energy, not definitely framed for some years later. He looked upon it as self-evident that a compound which gave out heat during combination, should take up precisely the same amount when its bonds were released, and that the thermal properties of a body were not dependent upon its history, but that the energy of combination in a compound was the same no matter how many transformations it had passed through or what path these followed. He was the author of the report on this subject to the British Association of 1849, in which a comprehensive survey was made of the then state of our knowledge. Towards the end of this period belongs a research on

the question of latent heat in many substances. Joseph Black first brought this doctrine into use, and it must be remembered that it is very closely connected with the ideas raised by the investigations into heat of chemical combination. It differs by being concerned only with the physical change of a substance. Black showed for example, that it required a large quantity of the entity called heat to cause the melting of ice, but this heat could not be perceived by the thermometer, as it had disappeared in the change of physical state. In like manner heat was required to convert the water into steam, and again the thermometer gave no indication of its presence, as the steam was at precisely the same temperature as the water from which it was being formed. In all such changes of state heat is either absorbed or given out; the quantities are perfectly measurable and are fixed, being always the same for the same change of condition. It is also the fact that the amount of heat required to raise the temperature of a substance, water for example, through some range between fixed limits, is always the same for the same substance under the same conditions and is proportional of course to the mass of substance dealt with. This is the specific heat of the substance, and the unit used is generally the quantity of heat required to raise one gramme through one degree C, from a fixed temperature. For fifty years it was believed that Regnault was right in his hypothesis that the specific heat of water was almost constant between 0° and 100°C, between freezing and boiling point, and all Andrews' experiments were made with this idea in view. In 1879 Rowland discovered the most unexpected fact that, instead of a constant, or a very slight but steady increase in the specific heat, the measure at 35° was almost one per cent. less than at 5°C. In the light of these results all Andrews' determinations need to be recalculated, as his values are given in terms of the mean between 0° and 100°, while his measurements were made at temperatures at which the specific heat is now known to be above the mean. I may illustrate this by his figures for water vapour.

He published in 1847 a series of eight experiments on water

vapour, one succession of three by a method which he believed would give values too high in amount, and five by another method which he was equally certain would give a figure too low. If we take the mean of those due to the first method and also of the five in the second series and use half the sum of these as the most probable value due to his experiments we find the resulting figure to be 537°, which means that the amount of heat required to convert say one pound of water at 100° into steam also at 100° is the same as would suffice to raise 5·37 pounds of water through the whole range between 0° and 100°C. But these figures are calculated on the understanding that the mean specific heat was constant. When they are recalculated in the light of modern knowledge, and of the most accurate experiments now on record, the figure of 537° becomes 538·3°, and we note also that the most modern value chosen for this quantity is 539·3°, arising out of experiments conducted with all the refinements of electric methods by which temperature can be measured to about one-thousandth of a degree. When Dr. Andrews made his experiments it was necessary to read the mercury thermometer to less than one one-hundredth of a degree to measure the variation between 538° and 539·3°.

I should next mention the series of experiments on Ozone, and here a short introduction is necessary. It had been noticed that a body having peculiar odour was formed under the following different circumstances, and that in each case its properties appeared to be similar :—

1. Passing electric sparks through air.

2. When water is decomposed by the electric current this substance appears at the positive pole along with oxygen.

3. By the slow oxidation of Phosphorous in air at ordinary temperatures.

For a long time the composition was uncertain, and it required experiment to determine if the same substance was formed in each of these cases.

It was believed by many chemists that the substance obtained

from the electrolysis of water contained hydrogen. Other scientists believed it to be composed wholly of oxygen. It was soon shown, however, that pure and dry oxygen could be partially converted into ozone by passing through it an electric spark.

It was also noticed that in the formation of ozone in oxygen the volume was reduced, and it was argued that ozone was an altered or allotropic form of oxygen, having a density greater than the parent gas. Andrews' experiments were undertaken to settle this question and he succeeded in proving that, no matter in what way Ozone was prepared, it was always the same body, with the same properties, and that that obtained from the electrolysis of water did not contain Hydrogen as had been supposed. It was found that Oxygen could only be partially changed into Ozone by the action of the spark, but it was also discovered that certain reagents seemed to absorb the Ozone when the combination took place, and that by continuing the process and absorbing the Ozone as formed, the whole of the Oxygen could thus be ultimately transformed. It was soon apparent that the amount of Ozone destroyed, as was supposed, by the chemical reagent used, and accounted for by its increase in weight corresponded approximately to the reduction in volume of the oxygen when the spark was passed through it. It was then necessary to investigate the matter further and discover the density of the allotropic modification of oxygen which he had proved to be formed. In 1857 the first account of the experiments undertaken in conjunction with P. G. Tait, then Professor of Mathematics in Belfast and a member of our society, appeared, and was followed by publication of a further series in 1859 and 1860.

Never was Andrews' unrivalled accuracy in experiment better shown than in this series, which ran up against a stone wall by suggesting an infinite density for Ozone. It is true that the two experimenters saw another solution to the difficulty, which was really the true solution, but which was named only to be rejected as too improbable. Soret later proved that the density of Ozone was one and a half times that of Oxygen, and that the solution rejected by Andrews and Tait was the true one.

The experimenters attempted to discover the density of Ozone when mixed with Oxygen on the assumption that the molecule was completely broken up and the resulting oxygen combined with the reagent employed. They weighed the reagent and found the volume of oxygen it had seized and then found that no volume whatever had been lost from the gas under consideration. Of course if a definite weight of any substance has no volume whatever its density must be infinite, yet the very accuracy of the experiment is seen in the fact that absolutely no change in the volume could be discovered.

If we represent Ozone by the formula $\begin{matrix} O \\ \wedge \\ O \equiv O \end{matrix}$ which is possible since the discovery of quadrivalency in Oxygen, we see at once what occurs. When the outer atom is removed from the molecule it will of course be in a very active condition and will be totally absorbed, while the remaining two atoms keep the molecular form, becoming bivalent. As the molecule in both cases has the volume of two atoms of Oxygen there will be no change whatever due to the tearing away of the loosely bound atom.

A rather interesting memory is connected with these Ozone investigations. When the paper was submitted for the Royal Society in 1860 it was handed to two referees for report. The curious result of the calculations seems to have raised doubt as to the accuracy of the experiments, but it is rather odd that I have found in Sir George Stokes' correspondence with Andrews, the statement that one of the referees still clung to the view that Ozone was a compound of Oxygen and Hydrogen, though all who read Andrews' first paper with attention will admit that he completely disproves this idea. Stokes was a firm and good friend to Dr. Andrews, and of course well known as a scientific investigator himself, but perhaps even better in his official position in regard to the Royal Society, of which he was secretary for so many years, and afterwards president. George Gabriel Stokes was a Sligo man, and was senior wrangler and first Smith's Prizeman in 1841. He was one of our really great mathematical

physicists and deserves to be remembered on the roll of our countrymen.

The only other research of Professor Andrews' which I shall mention is his great investigation which resulted in the Bakerian lectures of 1869 and 1876, on the "Continuity of the Liquid and Gaseous States."

A hundred years ago Caignard de La Tour heated a number of volatile liquids in sealed tubes, and noticed that, at a temperature which seemed fixed for each liquid, the meniscus of the surface gradually flattened out, and then, somewhat suddenly, the tube became filled with homogeneous matter. In 1826 Faraday succeeded in liquifying Chlorine, rather unexpectedly it must be admitted. He was then assistant to Davy, and was experimenting at his desire on several substances. He had sealed into a bent glass tube a small quantity of Hydrate of Chlorine Crystals, which are formed by exposing moist Chlorine gas to a temperature of 0°C. You will remember that it was Davy who proved that Chlorine was an element. When Faraday gently heated the crystals in one end of the bent tube some drops of an oily looking yellow liquid condensed in the other, the cool end. Of course the generation of the chlorine had greatly increased the pressure in the tube and caused partial liquefaction. There is a pleasant story to the effect that Dr. Paris entered the laboratory while this experiment was in progress, and after seeing the yellow drops scolded the worker for his carelessness in allowing the materials to be contaminated. Faraday answered nothing at the time, but the next morning Dr. Paris received a short letter reading—

"Your oily drops were nothing but Liquid Chlorine."

MICHAEL FARADAY.

In these experiments Faraday succeeded in liquefying a number of gases. He returned to the subject in 1845, when, by the joint application of pressure and cold he effected the liquefaction of a further number. He published the opinion that

the liquefaction of any gas was only a question of sufficient pressure and sufficient cold, and that there existed for each gas a temperature above which pressure alone, no matter how great, would not produce liquefaction. Faraday was one of the most intimate friends Andrews possessed. He was the son of a blacksmith and was both a scholar and a gentleman, though there is rather a malicious story as to Lady Davy and him. He accompanied Davy to Paris as his assistant, and in an emergency undertook to act as his valet. The French scientists were not long in discovering the nature of the young man they met, and placed him at dinner with Sir Humphry and his wife. It is said that Lady Davy was highly indignant that a servant should have such a position, and other arrangements had to be made for the rest of the visit.

It was about 1860 that Dr. Andrews began the experiments, which first took the form of an inquiry into the effect on various gases of combined pressure and cold. In this inquiry he used pressures as great as 500 atmospheres and a degree of cold approaching $-110°C$. Later on he devoted himself to an investigation of Carbon Dioxide, Carbonic Acid as it was then always called, with the view of discovering some law which might be connected with liquefaction generally, and in this he was eminently successful.

The apparatus used is shown in the engraving, fig. I. It consists essentially of two metallic tubes, to the upper flanges of which glass tubes can be connected. The two metallic tubes are in full communication at the bottom and are filled with water, so that the pressure in both will be alike, whatever its value. The tubes are of cold drawn copper, and the general arrangement is easily understood from the drawing. In my day at Queen's, Andrews was engaged in repeating and varying the experiments described in his Bakerian lecture of 1876, and at this time had improved the apparatus, by somewhat increasing the diameter of the metal tubes, and inserting the lower ends of the glass tubes into small glass reservoirs of mercury resting on ledges within the metallic

portions. The glass tubes were mounted in an ingenious way. An enlarged conical portion was formed near the junction of the two diameters, the lower ends of the tubes being comparatively large in diameter while the upper portions were of capillary dimensions. The lower mouth of the metallic flange was cone

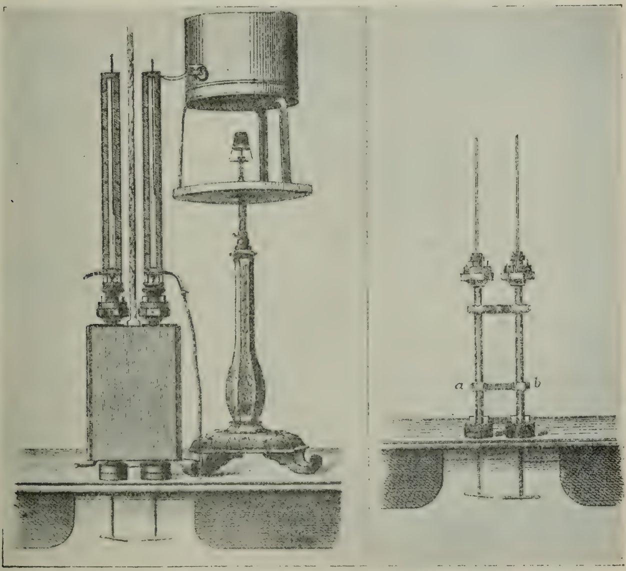


Fig. I.—Apparatus arranged for compression of CO_2.

shaped, fitting pretty well the cone on the glass tube. About the conical part of the glass tube and a short distance below it was wrapped a fine thread coated with shoemaker's wax. When the joint was to be made the metallic portion was warmed and the glass tubes pressed firmly into place and held until cool. This joint stood quite perfectly and gave no trouble.

The screws shown on the lower part were passed through leather washers steeped in vacuo in melted lard, and they also acted so perfectly that I have known the apparatus undisturbed under pressure for weeks and at the end reading identically as before the stoppage, when reduced for temperature and barometer. Of course the forcing in of the screws raised the pressure, two being used to increase the range. A stream of purified Carbonic Acid was passed through the tube for some hours and the capillary end sealed by heat while the lower portion was in the small reservoir approaching the surface of the mercury. A stream of the gas was continued past the open end for some time after sealing and then the tube was passed beneath the surface of the mercury, enclosing a measured volume of the gas, under barometer pressure and temperature carefully recorded. The volume of the tubes and the variations of internal diameter were very carefully measured by weighing mercury contents and by the usual calibrating method of passing a known quantity of mercury along tho tube and noting the variation in the length occupied. The result could be relied upon to about one part in a million. The volume of the gas was so calculated that the mercury began to show in the capillary part of the tube at a pressure of about forty atmospheres. Arrangements are shown in the drawing by which the required temperature could be maintained surrounding the tube with the Carbon Dioxide, while the air-tube, well screened from the heat of its neighbour, could be kept at the temperature chosen as the standard for the manometer.

The results of the experiments are shown in the diagram (fig. II), and can only be described briefly.

It was found that, below a certain temperature, the carbonic acid behaved as a partially saturated vapour, and that on adding pressure the compression at first proceeded in a way somewhat resembling that in a perfect gas, in which, so long as the temperature remains unchanged, the product of pressure by volume is constant, and a curve corresponding thereto would be an hyperbola. In the figure the curves show the actual relations

discovered between volume and pressure, the gas being compressed at a constant temperature in each case.

It is seen that within certain limits of pressure the curve in each case resembles an hyperbola, but that below the curve of

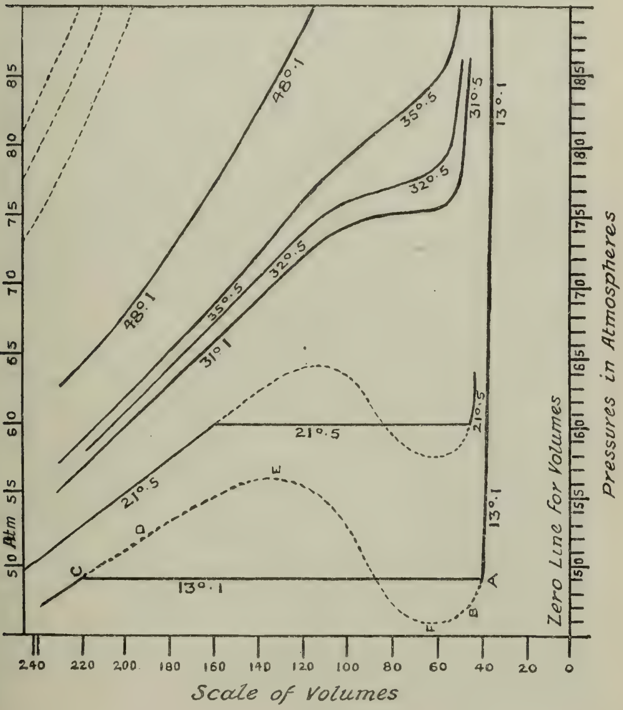


Fig. II.

The undulating dotted lines show James Thomson's theoretical isothermals for 13°·1 and 21°·5.

about 30°C, there is in each case a point at which the volume lessens as the screws are forced into the liquid in the reservoir tubes, while the pressure does not increase until a certain volume is reached at which this action ceases, and the pressure abruptly starts again to rise. The first point marks the beginning of the change into the liquid condition, while the second marks the completion of the change, when the gas is all liquefied, and the increasing pressure is only accompanied by such reduction of volume as corresponds with the gradual compression of the liquid thus formed. If the CO_2 were quite pure the line showing the process of liquefaction would be truly horizontal, but it proved to be impossible to remove the last vestige of air from the tubes, and it was found that from one five-hundredth to one thousandth part of the volume consisted of air, which is not liquefied under the conditions of the experiment, so that the line has a slight upward tendency corresponding to the increased pressure required to reduce the volnme of the air itself.

It will be noticed that, as the temperature is greater, this horizontal line in the isothermal curve becomes shorter, so that at a temperature approximative to 30°C., it becomes infinitely short : and at this point the curve has a point of inflexion. This is a critical point of liquefaction, and the particular temperature belonging to this isothermal line is called the critical temperature. It was defined by Andrews as that temperature below which liquefaction visibly occurs, and above which no pressure, however great, will cause a partial liquefaction, or at which the liquid can exist in presence of the gas He pointed out that the passage from the gaseous to the liquid condition may be made absolutely continuous, and for this reason chose as a title for his statement of results "The Continuity of the Liquid and Gaseous States."

The critical temperature is often defined as "that temperature above which no pressure, however great, will cause liquefaction to take place."

It does not seem that this is a logical statement, nor did Dr. Andrews ever teach in this form. It does not seem possible to show that liquefaction has not taken place when the gas has been sufficiently compressed above the critical temperature. It seems better to define the critical temperature as that above which any conversion of gas to liquid takes place with perfect continuity.

We may, however, frame a definition for "point of liquefaction" by referring to the isothermal curves. In every isothermal below the critical temperature there is a point of the curve in which the diagram shows a break in the nature of the line. This corresponds to the point at which liquefaction is taking place, at which the pressure remains constant while the volume decreases rapidly. If we accept the theoretical curves due to James Thomson—explained before our Society fifty years ago, and shown in figure II—there are two points on each of these curves at which the tangents are horizontal. These are points of liquefaction or the converse action. Between these points the substance is unstable. It may exist in either state, but tends very strongly to the condition usually apparent at the corresponding pressure. On the isothermal belonging to the critical temperature there is a point at which the two tangents coincide, and this becomes a point of inflexion and the critical points, the tangent becoming horizontal and also cutting the curve.

To put the result into mathematical language any tangent to the curve at which $\frac{dp}{dv} = 0$, marks a point of liquefaction, while at a critical point we have also $\frac{d^2p}{dv^2} = 0$.

The isothermal curve is therefore one of the third degree, and many equations have been framed to express this, some of which will be referred to later.

These experiments and conclusions of Professor Andrews form a great part of the foundation of the art of refrigeration.

One of the greatest of the French inventors in this development of industry says—"This remarkable scientific man very wisely turned his attention to a simpler problem, that of the liquefaction of Carbonic Acid. with a view to investigating its characteristics. From this investigation was destined to be born the general theory of liquefaction and the ideas, more than ever prevalent at the present time, on the Continuity of the Liquid and Gaseous States."

On hearing Andrews' paper shortly after the delivery of the Bakerian lecture of 1869, the then President of our Society, Joseph John Murphy, offered a suggestion for the calculation of the critical temperature of water, rather interesting under the circumstances. He argued that clearly the critical temperature was that at which the latent heat of conversion to vapour vanished. "if, then, we accept Reynault's equation," said Mr. Murphy, "throwing it into the form—Latent Heat $= 606{\cdot}5 - {\cdot}695t$, when the latent heat vanishes we have ${\cdot}695t = 606{\cdot}5$, or $t = 873°$C." Of course this temperature is far too high, but the error was in the equation and not in the method suggested. Reynault's equation gave fair values at moderate temperatures between 100° and 200°, but the equation representing the facts has a factor $\left(1 - \frac{v}{V}\right)$, where $v =$ volume in liquid form and V volume of same quantity in vapour, both taken at the temperature t. At 100° the term $\frac{v}{V}$ has a value of about 0·0006, so that $\left(1 - \frac{v}{V}\right)$ is very nearly unity. At 200° the value of $\frac{v}{V}$ is roughly 0·009, so that it is rapidly increasing yet still nearly negligible. At a temperature of about 250° the value of $\frac{v}{V}$ has risen to about 0·025, while about 374° v becomes equal to V, and the Latent Heat becomes zero. Thanks to the introduction of quartz tubes the critical point of water is measured fairly easily.

In 1876 Dr. Andrews, in his second Bakerian lecture, gave

an account of many experiments, the bearing of which was not immediately perceived. In comparing the behaviour of CO_2 at various temperatures and pressures, he deduced several laws connecting the different isothermals, but it is impossible to give any detailed account of the investigations. It is of interest, however, to consider one of the suggested laws and to connect it with some others offered by such men as Rankine and Van der Waal. His experiments showed that, for a great part of the range, the isothermal curves of the vapour approximately answered the equation $C = V(1 - Vp)$, where V is the volume, p the pressure, and C a constant. A perfect gas being represented by $Vp =$ constant, this equation of Andrews showed the departure of the vapour from the ideal. If two such equations on the same isothermal curve, in the form $\frac{C}{V_1} = 1 - V_1 P_1$ and $\frac{C}{V_2} = 1 - V_2 P_2$, be subtracted, the result is $\frac{C}{V_1} - \frac{C}{V_2} = V_2 P_2 - V_1 P_1$. If the equation be assumed true for the gas from a very low to a moderate pressure, then we may take P_2 as very low, and consequently $\frac{C}{V_2}$ may be supposed to vanish as P_2 becomes indefinitely small, leaving the form $\frac{C}{V} = R - VP$, where R is the ideal VP when P becomes very small. This then appears to be the true form of Andrews' equation, and if the proper corrections are made for the presence of air, &c., it represents the true facts within reasonable limits of pressure. It may obviously be thrown into the form $R = V\left(P + \frac{C}{V^2}\right)$. For very high pressures this is obviously untrue. It becomes necessary to have a factor which vanishes when P is infinite, and this is found by writing $(V - a)$ instead of V as the factor outside the bracket, when a must be the limit of volume of the gas as P becomes very great, This then gives Van der Waals' equation $(V - a)\left(P + \frac{C}{V^2}\right)$. With

proper values for a and C this equation gives a very good approximation to the experimental results, as long as the gaseous condition is plainly present, but at very high pressures a small error in a or V introduces so great a change in the results that it is useless under such circumstances.

Again, in the equation $\frac{C}{V_1} - \frac{C}{V_2} = V_2 P_2 - V_1 P_1$, representing the relation between two points on the same isothermal, if P_2 is unity, and by the conditions of the experiments V_2 also unity, the equation becomes $\frac{C}{V} = \underline{1 + C} - VP$, but comparing this with previous results it is plain that $\underline{1 + C}$ is sensibly equal to R, as already defined, and an equation resembling Rankine's simple form appears $\frac{R}{V} - \frac{C}{V^2} = P$.

Again, this represents the results better if the first term be assumed as $\frac{R}{V - a}$, where a has the value already mentioned. Thus Rankine's, Van der Waals', and also Clausius' equations are very closely related to this simple approximation due to Andrews. The connection between different temperatures was also investigated, and valuable results obtained. In his later experiments upon the behaviour of mixed gases under changes of temperature and pressure, some results were obtained, the value of which was not apparent until the liquefaction of air became an economic success.

It is impossible to follow Andrews' work further in such a sketch as this. It is well, however, to remind the reader of the very remarkable anticipation of the results of the experiment on the critical condition, which is found in the hypothesis framed by Mendeleëff at the very time Andrews was completing his experimental work. He predicates a condition in which, by combination of temperature and pressure, a vapour becomes of the same density as its liquid under the same circumstances, and concludes

that, at this point, which he calls the absolute boiling point, the latent heat becomes zero.

I should like to say a few words about the services of Dr. Andrews in another than the scientific side of his work. He was the leading spirit in the foundation of the Queen's University of Ireland. It is not generally understood that the first idea of the Government was to establish three Colleges in Ireland for the general education in Arts of the middle classes without the purpose of forming them into a University. There was not, apparently, any intention of providing professional education in such subjects as Medicine and Engineering. Dr. Kane in his report seems to have taken this for granted, but Dr. Andrews vigorously combated this view. I have the rough draft of a memorandum in his hand-writing, in which he urges that the Government must take up the work of framing a University, as the Colleges could never be maintained in a working condition unless this were done. He also argues that the neglect of the special education required for those proceeding to qualify for the professions will drive large numbers of the possible students to other centres of learning, and that it will be impossible to fill the class-rooms with those anxious only to obtain an education in the usual Arts courses. He sketches an arrangement for a Medical School, almost completely agreeing with that provided later when the College was opened, and suggests that, on the provision of such facilities, the Medical School then in operation in the Royal Academical Institution should be discontinued, and the Institution should completely revert to its original purpose of providing a first-rate secondary education for the youth of the middle class inhabitants.

Dr. Andrews always remained greatly interested in educational schemes, and published a most interesting and powerful pamphlet, entitled "Studium Generale," explaining his views, which have since come to fruition, at least to a large extent, in the Queen's University of Belfast.

The following is a list of the papers contributed to our Society by Dr. Andrews, and will be interesting to our members :—

6th April, 1836.—Construction of electro magnets.

4th October, 1837.—Electrical conduction.

17th January, 1838.—Flame and the oxy-hydrogen blow-pipe.

6th February, 1840.—Some recent applications of galvanism to the arts.

31st March, 1841.—Radiant heat.

10th March, 1842.—On the subject of heat.

15th February, 1843.—On the heat of combination.

31st January, 1844.—On animal heat.

23rd April, 1845.—Some recent discoveries in organic chemistry.

13th May, 1846.—An account of Dr. Faraday's recent discoveries in magnetism.

4th November, 1846.—The heat developed in combustion and other cases of chemical action.

30th December, 1846.—The construction and method of using certain meteorological instruments.

16th April, 1851.—(1) On certain applications of polarised light to chemical analysis; (2) on the presence of magnesia in magnetic iron ore.

17th December, 1851.—On the spheroidal condition of bodies.

9th March, 1853.—Communication on the construction and use of certain meteorological instruments and results obtained during the previous two years at Queen's College.

8th March, 1854.—Composition and properties of ozone.

15th November, 1854.—Photography.

18th March, 1857.—Preparation and properties of aluminium.

4th November, 1857.—The manufacture of stearic acid and other analogous bodies employed for illuminating purposes.

19th January, 1859.—The metals of the alkalies and alkaline earth.

7th March, 1860.—Recent researches regarding the properties of some of the chemical elements.

2nd May, 1866.—Spectrum analysis.

8th April, 1868.—Atmospheric ozone.

17th February, 1869.—The mechanical analysis of rocks.

23rd February, 1870.—The continuity of the liquid and gaseous states of matter.

3rd March, 1875.—The analysis of the Ballynahinch water.

17th March, 1875.—Electro-magnetic machines and the recent improvements on them by M. Gramme.

It is interesting to note, that in 1902, thirty-two years after Dr. Andrews' paper in 1870 "The liquefication of gases and the continuity of state," was the subject of an address at the Belfast meeting of the British Association by the then President, Sir James Dewar.

As an appendix to one of his lectures before the Royal Society, Dr. Andrews printed for the first, and possibly the only time, several letters from M. Lavoisier to Dr. Joseph Black. To render these letters more generally accessible they are reprinted here. The reader is referred to p. 49, Proceedings of Society, 1919-20, for some account of Black and his Belfast connections.

LETTERS FROM M. LAVOISIER TO DR. BLACK.

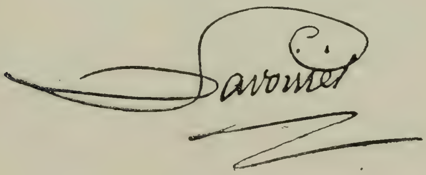
Paris le 19 Septembre, 1789.

Monsieur,—C'est un membre de l'académie Royale des Sciences de Paris qui vous écrit à titre de Confrère : c'est un des plus zélés admirateurs de la profondeur de votre génie et des importantes révolutions que vos découvertes ont occasionées dans les Sciences, qui profite, pour avoir l'honneur de vous écrire, de l'occasion de M. de Boullogne qui va finir son éducation à Edimbourg. Permettez-moi de vous le recommander. Il joint à d'heureuses dispositions un grand désir de s'instruire et il regarde comme un grand bonheur pour lui d'avoir une occasion pour se présenter à vous. Il a bien voulu, Monsieur, se charger de vous remettre un exemplaire d'un ouvrage que je viens de publier : vous y trouverez une partie des idées dont vous avez jetté le premier germe : si vous avez la bonté de donner quelques instants à sa lecture, vous y trouverez le développement d'une Doctrine nouvelle que je crois plus simple et plus d'accord avec les faits que celle du Phlogistique. Ce n'est au surplus qu'en tremblant que je le soumets au premier de mes juges et à celui dont j'ambitionnerais le plus le suffrage.

J'ai l'honneur d'être très-respectueusement,

Monsieur,

Votre très-humble et très-obéissant Serviteur,



Paris, 24 Juillet, 1790.

Monsieur,—J'apprends avec une joye inexprimable que vous voulez bien attacher quelque mérite aux idées que j'ai professé le premier contre la doctrine du phlogistique. Plus confiant dans vos idées que dans les miennes propres, accoutumé à vous regarder comme mon maitre, j'étois en défiance contre moi-même tant que je me suis écarté sans votre aveu de la route que vous avez si glorieusement suivie. Votre approbation, Monsieur, dissipe mes inquiétudes et me donne un nouveau courage.

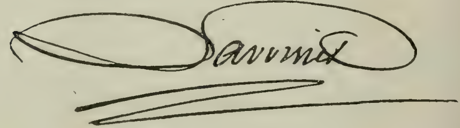
Cette Lettre, Monsieur, vous sera remise par M. Terray intendant de Lyon neveu du Ministre des finances de ce même nom et mon parent ; il conduit à Edimbourg son fils, jeune homme d'espérance et destiné a posséder une grande fortune, pour y finir son éducation et suivre les leçons des professeurs célèbres de l'université d'Edimbourg. Permettez-moi, Monsieur, de vous le recommander. L'intérêt que vous voudrez bien prendre à lui sera un premier titre qui l'annoncera d'une manière avantageuse et j'ai lieu de croire qu'il ne se rendra pas indigne de vos bontés.

Je ne serai pas content jusqu'à ce que les circonstances me permettent de vous aller porter moi-même le témoignage de mon admiration et de me ranger au nombre de vos disciples. La révolution qui s'opère en France devant naturellement rendre inutile une partie de ceux attachés à l'ancienne administration, il est possible que je jouisse de plus de liberté ; et le premier usage que j'en ferai sera de voyager et de voyager surtout en Angleterre et à Edimbourg pour vous y voir, pour vous y entendre et profiter de vos lumières et de vos conseils.

J'ai commencé un grand nombre d'ouvrages et de travaux et j'aspire à un Etat de tranquillité qui me permette d'y mettre la dernière main.

J'ai l'honneur d'être très-respectueusement.

Monsieur,
Votre très-humble et très-
obéissant serviteur.



M. Black, de l'académie des sciences,

Paris, le 19 Novembre, 1790.

M. Terray, Monsieur, m'a remis, en arrivant à Paris la lettre que vous m'avez fait l'honneur de m'écrire le 24 Octobre ; il ne pouvait me faire un présent qui me fût plus agréable. J'ai cru que vous ne désapprouveriez pas que je la communiquasse à l'Académie des Sciences ; elle n'a pas moins admire l'élégance du style que la profondeur de philosophie et la candeur qui règne dans votre lettre, et elle a même désiré qu'elle fût déposée dans ses registres ; mais je n'y ai consenti, qu'à condition qu'il m'en serait remis une copie certifiée du secrétaire. J'ai une autre grace à vous demander, mais sur laquelle je dois attendre votre aveu ; c'est de vouloir bien me permettre d'en publier la traduction dans les Annales de Chimie.

M. Gillan a été témoin, depuis son séjour à Paris, de quelques expériences que j'ai faites sur la respiration et il a bien voulu y concourir. Nous nous sommes assurés des faits suivans :

1°. La quantité d'air vital ou gaz oxigène qu'un homme en repos et à jeun consomme, ou plutot convertit en air fixe ou acide carbonique, pendant une heure est de 1200 pouces cubiques de France environ, quand il est placé dans une température de 26 degrés.

2°. Cette quantité s'élève à 1400 pouces, dans les mêmes circonstances, si la personne est placée dans une température de 12 degrés seulement.

3°. La quantité de gaz oxigène consommée, ou convertie en acide carbonique, augmente pendant le tems de la digestion et s'élève à 1800 ou 1900 pouces.

4°. Par le mouvement et l'exercice on la porte jusqu'à 4000 pouces par heure et même davantage.

5°. La chaleur animale est constamment la même, dans tous ces cas.

6°. Les animaux peuvent vivre dans de l'air vital ou gaz oxigène, qui ne se renouvelle pas, aussi longtems que l'on le juge à propos, pourvu qu'on ait soin d'absorber, par de l'alcali caustique en liqueur, le gaz acide carbonique, à mesure qu'il se forme ; en sorte que ce gaz n'a pas besoin, comme on le croyait, pour être salubre et propre à la respiration d'être mélangé avec une certaine portion de gaz azote ou Mophete.

7°. Les animaux ne paroissent pas souffrir dans un mélange de 15 parties de gaz azote et d'une partie de gaz oxigène, pourvu qu'on ait de même la précaution d'absorber le gaz acide carbonique, par le moyen de l'alcali caustique, à mesure qu'il est formé.

8°. La consommation du gaz oxigène et sa conversion en acide carbonique est la même dans le gaz oxigène pur et dans le gaz oxigène mêlé de gaz azote, en sorte que la respiration n'est nullement accélérée en raison de la pureté de l'air.

9°. Les animaux vivent assez longtems dans un mélange de deux parties de gaz inflammable et d'une de gaz oxigène.

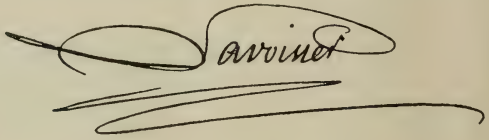
10°. Le gaz azote ne sert absolument à rien dans l'acte de la respiration et il ressort du poumon en même quantité et qualité qu'il y est entré.

11°. Lorsque par l'exercice et le mouvement on augmente la consommation de gaz oxigène dans le poumon, la circulation s'accélère ; ce dont il est facile de s'assurer par le battement du poulx : et en général lorsque la personne respire sans se gêner, la quantité de gaz oxigène consommée est proportionnelle à l'augmentation du nombre des pulsations multiplié par le nombre des inspirations.

Il est bien juste, Monsieur, que vous soyez un des premiers informés des progrès qui se font dans une carrière que vous avez ouverte, et dans laquelle nous nous regardons tous comme vos disciples. Nous suivons les mêmes expériences, et j'aurai l'honneur de vous faire part de mes découvertes ultérieures.

J'ai l'honneur d'être avec un respectueux attachement, Monsieur,

Votre très-humble et très-obéissant Serviteur,



BELFAST

NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.

PROCEEDINGS,

SESSION 1920-1921.

No. 4.

ABSTRACTS OF LECTURES,

ANNUAL REPORTS,

LIST OF MEMBERS, &c.

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1922.

11th January, 1921.

Professor GREGG WILSON, President of the Society, in the Chair.

PUBLIC LECTURE IN ASSEMBLY MINOR HALL,

entitled :

THE WONDERLAND OF THE WASPS.

By JOHN J. WARD, F.E.S.

(*Abstract.*)

In introducing his subject the lecturer referred to certain wasp mimics, insects masquerading as wasps, and deriving protection from their black and yellow covering and wasp-like appearance; and in this connection showed slides of the wasp beetle, hover fly, and the lunar hornet moth. The life story of the latter insect was told in detail and illustrated by means of wonderful photographs, and incidentally introduced a parasitic enemy—the long-tailed ichneumon wasp.

The wasps were divided into two great classes, namely, the Solitary and the Social species. Then came astonishing revelations of the life histories of various solitary species, almost unbelievable wonders observed by the lecturer were demonstrated on the screen by means of his instructive photographs. The life story of the Mud Wasp (*Odynerus antilope*), Mr. Ward stated, had taken him seven years to work out in detail. The little wasp appeared for only about three weeks during the month of June, building its nesting cells on a flat brick wall, preferably that of a newly-built house. The cells were constructed with a kind of cement, which the wasp manufactured by scraping a piece of sandstone with its mandibles and then mixing the sand grains so obtained with saliva. When a cell was made the wasp then stored it with live caterpillars, which it captured, and, with

the skill of an experienced surgeon, stung so as to paralyze, but not to kill. After each caterpillar was in this manner placed under an anesthetic, it was then carried by the wasp to the cell and there stored, from eight to sixteen of them, packed like sardines in a box. The wasp then deposited an egg in the cell and sealed it up. In that way it provided its offspring with fresh meat. The whole development of the wasp grub was shown from the egg stage until it completed its metamorphoses and appeared as a fully-developed wasp.

Details were also revealed of the natural enemies of the mud wasp, one of which was the common blue tit, and particularly interesting were the gorgeously-coloured cuckoo wasps, which came and deposited their eggs in the cells of the mud wasp before they were sealed up.

Leaving the solitary species, the lecturer then dealt with the social species, which included the common wasp. These consisted of tree wasps and ground wasps. The former built their nests in trees in the open sunlight, and the latter below ground in darkness. After describing the anatomy of the mouth parts of the common wasp, and also that of its stinging organs, the nests of tree wasps were described. The final part of the lecture was devoted to the complete story of the building of the nest of the common ground wasp, from the time when the queen leaves her hibernating place at the beginning of May and commences to build a new wasp city at the end of a mouse run of the previous summer. The queen wasp was shown with the little nest she had constructed quite unaided. It was no larger than a five-shilling piece, but after her first offspring appeared it soon grew apace, and eventually became as big as a four-pound loaf.

Mr. Ward displayed astonishing photographs showing the combs of the nest with their hosts of worker wasps carrying on their functions. At this stage the queen wasp had nothing to do but deposit eggs in the thousands of cells being made by the workers. The latter carry on all the work of the nest, building, feeding and tending the young wasp grubs, excavating the soil,

etc. Eventually the queen wasp became the mother of from 20,000 to 60,000 wasps. As autumn approached, dome-shaped cells appeared, and from these emerged the young queens and their suitors, the males, to carry on the generations for the next year. Photographs showed the wasps biting their way out of the cells as they matured, and the cells being cleaned and prepared almost immediately for another egg to be placed in them by the queen, for they could be used three times during one summer. One slide displayed a comb containing over 4,000 cells, which used three times would represent 12,000 wasps, and the nest often contained ten combs, although not all so large as that one. At the first signs of wintry weather the worker wasps quickly perished, and the nest soon became a complete ruin, only the young queens could live through the winter, each surviving one would then become the mother of a new wasp colony the following year.

At the conclusion of the lecture the Chairman said while there would be no formal vote of thanks, he would ask the audience to express their appreciation of the brilliant and most fascinating lecture they had just listened to. He thought the interest with which the lecture had been followed had been felt by the lecturer throughout the evening, and that was the best thanks they could give to him.

25th January, 1921.

Professor Gregg Wilson, President of the Society, in the Chair.

In Museum, College Square North.

"ART AND WORKMANSHIP."

By Ivor Beaumont, A.R.C.A., M.S.A., F.R.S.A., F.I.B.D., Head Master, School of Art, Municipal College of Technology, Belfast.

(*Abstract.*)

Mr. Beaumont said, broadly speaking, art was connected with all the works of man which were primarily meant to satisfy the aesthetic instinct. The craving for beauty and harmony was inherent in all human beings. By Works of Art he did not mean only those things which appeal to the eye and touch ; in the term "Art" he included all manifestations which arose out of and tended towards the satisfying of man's desire for beauty and harmony. Art was therefore rarely divorced from industry ; art was indispensable in life, and it should have an important place in the course of general education. In conclusion, Mr. Beaumont said it should never be forgotten that Schools of Art were provided for the industries and not the industries for the Schools of Art. Once they got that fact fixed in their minds, they would take care that the training given in the Schools of Art was thoroughly practical, and that students were properly fitted to take their place in the industries which they intended to enter.

The lecture was illustrated with a beautiful series of lantern slides, and at the close a hearty vote of thanks was passed to the lecturer.

8th February, 1921.

The President, Professor Gregg Wilson, in the Chair.

In Museum, College Square North.

THE DECORTICATION OF FIBROUS PLANTS,

WITH SPECIAL REFERENCE TO

FLAX RETTING AND SCUTCHING.

By H. R. Carter.

(Abstract.)

Mr. Carter, in the course of his remarks, said that it has been aptly stated that "the Great War was won by Belfast wings," the Ulster capital providing the bulk of the aeroplane linen. The cultivation, retting, scutching, and spinning of flax was one of Ulster's greatest industries.

Mr. Carter divided vegetable fibres into three classes namely, those obtained from the bark of the plants, such as flax, true hemp, jute and ramie ; those derived from the more or less fleshy leaves, or from the part of the plant enclosed by the bark, including Sisal, New Zealand hemp, and other hard cordage fibres ; and thirdly, fibres derived from the seed pods of which the principal are cotton and coir.

Of these three classes, only the first two require processes of decortication, and of course the treatment of the flax plant is that of special interest in Ireland.

The lecturer displayed excellent lantern illustrations of the various processes in connection with the treatment of this fibre, laying special stress upon the highly scientific methods of growing and preparation of the fibre in vogue in the valley of the river Lys in Belgium. From this district is derived the best and finest quality of flax fibre in the world, and he emphasised the

importance to Ireland of these methods being more fully adopted in this country. Irish flax, if properly treated agriculturally, is quite equal to that grown in Belgium or Holland; lax and unscientific methods of growing, retting, scutching and general handling, however, reduce its market value considerably as compared with the product of Belgium and Holland.

A vote of thanks to the lecturer brought an interesting address to a conclusion.

ANNUAL MEETING.

100TH SESSION, 1920-21.

The Annual Meeting of the Shareholders and Members was held in the Museum, College Square North, on the 21st November, 1921. Professor Gregg Wilson, O.B.E., M.A., D.Sc., Ph.D., President, occupied the Chair, and among those present were :—Sir Charles Brett, LL.D. ; Alderman S. T. Mercier, J.P. ; Messrs. H. C. Lawlor, M.R.I.A. ; William Faren, Godfrey Ferguson, J.P. ; W. B. Burroughs, T. Edens Osborne, W. M. Crawford, Victor Salter, and Arthur Deane, Hon. Secretary. Apologies for absence were announced from Sir Frederick Moneypenny, C.B.E., C.V.O. ; Dr. S. W. Allworthy, M.A., F.G.S. ; Dr. Gawin Orr, Councillor E. J. Elliott, Mr. R. M. Young, M.A., M.R.I.A. ; Mr. Henry Riddell, M.E., M.I.Mech.E. ; Mr. J. M. Finnegan, B.A., B.Sc., and Mr. Alexander Milligan.

The Chairman called upon the Hon. Secretary to read the notice convening the meeting, and also the Annual Report of the Council, which was as follows :—

The Council has pleasure in presenting to Shareholders and Members of the Society the Annual Report and Statement of Receipts and Expenditure for the 100th Session of the Society.

OBITUARY.

It is with deep regret the Council records the loss by death of Mr. Burton Sefton, Mr. James Moore, and the Rev. Canon H. W. Lett, M.R.I.A. Mr. James Moore was a member of an old merchant family in Belfast. Every one knows the old-fashioned front of the warehouse in Donegall Place, about the

only one in that thoroughfare which has remained unchanged for more than sixty years. Mr. Moore was a member of our Society for many years He was a kindly-hearted and courteous gentleman, and his loss will be greatly felt. Canon Lett's death leaves a gap in the ranks of Northern Naturalists. He devoted considerable time to the study of the lower Irish Cryptogams and to Irish Archaeology, both prehistoric and ecclesiastical. He was born at Hillsborough on the 4th December, 1836, and died at Aghaderg on the 26th December, 1920, at the age of 84.

Mr. Burton Sefton was one of the members who joined the Society through the new scheme of membership. He took a great interest in our proceedings, and died in August last.

MEMBERSHIP.

The total number of Shareholders and Members at the end of session was 291. Your Council has had under consideration the propriety of creating life members on the basis of one payment, but it was decided to postpone further consideration of this proposal for one year.

Your Council has observed with great satisfaction that our oldest member, namely, Sir Charles Brett, has had conferred upon him the LL.D. degree, *Honoris Causâ*, of the Queen's University, Belfast, and that the Vice-Chancellor of the University (The Right Hon. the Rev. Thomas Hamilton, M.A., D.D., LL.D.), another old member of the Society, has been appointed a member of His Majesty's Privy Council in Ireland.

LECTURES.

Your Council records with pleasure that the Programme of Lectures arranged for the 100th Session was the best in the history of the Society. The Council feels that the Society is worthily fulfilling the wishes of the early members in the efforts

made to-day to diffuse useful knowledge among the citizens by means of popular addresses and short courses of lectures. It is interesting to note that arrangements for short courses were commenced as early as 1837, when Dr. James Drummond Marshall delivered a course of twelve lectures on "Birds: their classification, geographical distribution, and habits."

A good deal of original work was brought before the Society by some of the lecturers. The Council would like to point out that the publication of a programme does not in any sense preclude the reading of original papers, which may be submitted to the Council during the session.

A list of the lectures delivered during the period covered by this report will be found in Appendix, p. 158.

COUNCIL'S THANKS.

The Council is again indebted to the Vice-Chancellor of Queen's University (The Right Hon. the Rev. Thomas Hamilton) for granting your Society accommodation in the University. On this occasion two courses were delivered by two University Professors, namely, Professor A. W. Stewart and Professor James Small. To these gentlemen the Council tenders, on behalf of the Society, its sincere thanks for the continued co-operation between the University and our Society. As far back as 1858 Dr. Thomas Andrews, F.R.S., M.R.I.A., Professor of Chemistry, and Vice-President of Queen's College, delivered a course of six lectures on Chemistry in the Chemical Lecture Theatre at Queen's College, under the auspices of the Society.

The Council also desires to express its best thanks for the assistance rendered by the other lecturers during the session, and to the local Press for the full reports of the various meetings.

CENTENARY VOLUME.

Your Council has had under consideration the compilation of a Centenary Volume, giving a history of the Society, with a series of memoirs of the distinguished men connected with the Society in the past. This work is well in hand, and the Council hopes to publish this volume during the present session.

EXCHANGES.

Your Council continues to receive in exchange various publications, both home and foreign, from kindred societies, many of which are of great importance. The Council regrets, however, to report that the American Geographical Society has intimated that it proposes to limit its exchange list to those publications which are distinctly geographical in character. Application for back numbers of our Proceedings have been received from the following:—

The Brooklyn Museum.
New York Public Library.
New York Academy of Science.
Museum of Comparative Zoology, Cambridge, Mass.
United States Department of Agriculture.
Department of Agriculture, Canada.
The Patent Office Library, London.

A number of publications were also received from the Committee of the Ulster Fisheries and Biology Association on the winding-up of the Association.

ARCHAEOLOGICAL SECTION.

A separate report of the Archaeological Section will be submitted to the members by its Hon. Secretary, Mr. H. C. Lawlor, M.R.I.A., at the Annual Meeting of the Section, which is to be held on Monday, the 28th instant.

ELECTION OF COUNCIL.

In accordance with the constitution of the Society, the five following members retire by rotation from the Council :— Mr. J. M. Finnegan, Mr. Henry Riddell, Mr. R. M. Young, Professor Lindsay, and Professor Symmers. The two last named are ineligible for re-election.

HON. TREASURER'S STATEMENT.

The Hon. Treasurer (Mr. Henry Riddell) is unable to be with us this afternoon owing to an unfortunate accident which occurred to him some weeks ago, and which necessitated an operation. The Council is glad to report that he has made satisfactory progress, and hopes to be among us again soon. He has laid upon the table the Statement of Accounts which has been passed by the Local Government Board Auditor, and which will appear on p. 160 of the printed report, and submits a report which will be read to the meeting.

LOYAL ADDRESS.

Your Council, on behalf of the Society, submitted a loyal and dutiful address on the occasion of the visit of Their Most Gracious Majesties King George V. and Queen Mary, to open the Parliament of Northern Ireland, on the 22nd June, 1921. The time at the disposal of their Majesties, however, was not sufficient to allow of a personal presentation of the address, but it was duly acknowledged later by Lord Stamfordham, Private Secretary to His Majesty.

HON. TREASURER'S REPORT

For Year ending June 30th, 1921.

Both the Society and the Section for Archaeological Study are to be congratulated on a year of considerable progress.

The joint subscriptions for the year amount to One Hundred and Fifty-Four Pounds Seventeen Shillings, being an increase upon the previous year of almost thirty-five per cent. It will be seen, when the Balance Sheet is sent out to the Members, that the expenditure during the past year exceeded the income by over One Hundred Pounds, and the Local Government Board Auditor, in his report, calls attention to this fact.

It will be remembered, however, that attention was called last year to the fact that the balance-sheet then presented gave too favourable an impression of the finances, owing to the fact that the printers had not furnished their accounts for a great part of the Session, and that the Archaeological Section had on deposit with the parent Society a sum of Ninety-three Pounds.

The printed accounts appear in the present statement, and the balance of the Archaeological Section is now reduced to about Seventy Pounds. Every care and foresight is exercised with regard to the finances, and the members may be assured that nothing is spent which cannot be afforded. The cost of printing has been exceedingly heavy, but of course may be expected to fall with the decreasing cost of production. It is felt that neither the Council nor the members of the Society would urge any curtailment of the reports of proceedings, unless such were absolutely necessary.

Very many of our members cannot attend the meetings, and the Proceedings form the only connection they can have with the Society. It is evident also, from the frequent demands from outside bodies, that they arouse much interest. They are also the source of exchanges of the most extraordinary value, which will in the future form an important library.

ADOPTION OF REPORTS.

The Chairman, in moving the adoption of the Reports, said the Society had had a very busy year, and had very large audiences at all their meetings, some of which were as interesting

as any he had ever attended in Belfast. He hoped in the future they would manage to keep the Society as active as it had been recently. In regard to finances, while they were not in funds, they were rapidly coming to the day when they would have a little money to spare as they used to have. They were much indebted to their Hon. Treasurer (Mr. Henry Riddell) for the care he had taken to keep them as far as possible in good financial position, which was a very important matter in these days. In conclusion, the Chairman spoke of the valuable work of Mr. Riddell and the Hon. Secretary on behalf of the Society, and especially in connection with the Centenary Volume

Alderman S. T. Mercier, in seconding the resolution, said he had the pleasure of attending many of the lectures, and had found them most helpful and beneficial. If they found the Society was getting into financial difficulties, he suggested that a small fee should be charged for admission to the lectures, which at present were free.

VOTE OF THANKS TO PRESIDENT.

Mr. H. C. Lawlor, M.R.I.A., moved a vote of thanks to the outgoing President (Professor Gregg Wilson) for his valuable services during the past two years. The Society, he said, would always remember with pleasure Professor Wilson's term of office. This was seconded by Sir Charles Brett, LL.D., who also spoke in appreciative terms of Professor Wilson's services, and this was very heartily adopted.

On the motion of Mr. T. Edens Osborne, seconded by Mr. Godfrey Ferguson, it was unanimously agreed that the Hon. Secretary should convey to Mr. Henry Riddell the feelings of the members present in that they were gratified to know that he was recovering from his recent accident, and that they express to him the hope that he would soon be among them again.

ELECTION OF COUNCIL MEMBERS.

Messrs. J. M. Finnegan, Henry Riddell, and R. M. Young were re-elected Members of the Council for three years, retiring in 1924; together with Professor Morton and Professor A. W. Stewart.

The new Council held a meeting after the conclusion of the Annual Meeting, when the office-bearers were elected for the Session 1921-22. These, together with the Council of Management, will be found on page 162.

ARCHAEOLOGICAL SECTION.

Annual Meeting.

The Fifth Annual Meeting of the Section was held in the Old Museum on Monday, the 28th November, at 3-45 p.m., Sir Charles Brett, LL.D., in the chair.

The minutes of the previous Annual Meeting were read and confirmed. In the unavoidable absence of the Hon. Treasurer, Mr. Henry Riddell, through indisposition, the financial report was read by the Hon. Secretary of the Section. The balance-sheet, made up to June 30th, is given on page 161, showing a balance to credit of the Section at that date of £70 11s. 4d. To this must be added a little over £30 arising from current year's subscriptions and subsidy from the parent Society, less a few outstanding accounts, leaving slightly over £100 in hand, avail-for the work of the coming season.

The Hon. Secretary of the Section read a report on the work of the Section during the past year. In the early part of the season he had issued to all the members and some others likely to be interested, invitations to suggest subjects for investigation, under the auspices of the Section. The replies to this circular were gratifying, and were laid before a meeting of the Executive

Committee on June 16th—Sir Charles Brett presiding. Sixteen monuments of archaeological interest were recommended for investigation by the Section, mostly by members, and a few by non-members. These were carefully considered, and all recorded in the minutes for future reference. Out of the sixteen the following were selected as being of most importance :—

1. The ecclesiastical remains on Mahee Island, anciently Nendrum, in Strangford Lough.
2. Further excavations in Rathkeltchar in the field north and north-east of the Cathedral.
3. The Castle and Abbey site of Portmuck, Islandmagee.
4. The Stone circle at Kilmakee, Templepatrick.
5. The Cromlec at Slieve na Griddle in Lecale.
6. Harryville Moat, Ballymena.

The Committee considered that the proper execution of the investigation and preservation of the remains at Mahee Island would entail greater expenditure of money than the funds at their disposal permitted, and this work was deferred.

With regard to Rathkeltchar, it was considered by a majority that further investigation would fortify the conclusions arrived at from last year's investigations, and a grant of £30 was voted towards the object, the Hon. Secretary being instructed to communicate with the Downpatrick members who had helped in this work last year, and to arrange, if possible, for this work to be carried out in the July holidays. It was considered that this grant depleted the sum at the disposal of the Section sufficiently for the time, and that the remaining selected subjects for investigation be let lie in abeyance for future consideration.

A further meeting of the Executive Committee was held on the 27th July,—Sir Charles Brett presiding. The Hon. Secretary stated that arrangements had been practically completed for the work at Rathkeltchar to be carried out during the July holidays, when owing to the drought then prevailing, and the consequent shortage of grass, the tenant of the grazing, at the

last moment, withheld his permission to carry out the work, which had therefore been abandoned for the present. The Executive Committee then allotted the following grants for three of the other objects considered at the meeting in June 16th :—

To Major Thompson, D.S.O., for the investigation of the Castle and Abbey Site of Portmuck, Islandmagee—£25.

To the Rev. William Adams, M.A., for the investigation of Kilmakee Stone Circle—£15.

To Colonel Berry, M.R.I.A., for the investigation of the Cromlec at Slieve na Griddle—£5.

Owing to various unforseen circumstances, none of these grants had been taken advantage of, and while it was to be regretted that no actual excavation work had been carried out during the year, it was satisfactory that consequently the funds available for future work were so much greater.

Ancient Grave at Crea, Killyleagh.—In April the Hon. Secretary received a communication from Mr. James Heron, D.L., of Tullyverey, Killyleagh, to the effect that a remarkable prehistoric grave had been discovered in a rath in the townland of Crea, on the farm of Mr. Boyd, and requesting him to inspect the same, and record the find in the Society's reports. He accordingly visited the site in company with Mr. Heron and Mr. Boyd.

The rath, if it is one, is of somewhat unusual formation. It is situated on the summit of a small hill in the middle of a field. It is from 8′ to 12′ high above the somewhat uneven contour of the ground ; it is flat on top with no rampart, and no surrounding trench or vallum ; the diameter measured (on the top) about 27 paces.

Mr. Boyd, to cover a bare spot in his field, had removed a few cart loads of soil from the side of the rath or mound. In doing so, he removed a flat stone which had been placed on its edge. The removal of this stone disclosed the end of a stone-lined grave, measuring 5′ 8″ long, by 14″ wide, and 11″ high,

internal measurement. The grave lay due East and West; lying within were the remains of a skeleton, which he raked out and buried a few feet from the grave. No relics of any kind were found with the remains.

The grave was of a class exactly similar to those so frequently found in the Abbey field at Portmuck, and at Gransha, Islandmagee, in which coins of the first Edwards were found, that it is possible that it dates as late as between the 12th and 14th centuries; it may be earlier, but from its orientation and similarity to graves known to be mediaeval, it may be regarded as certainly not pre-Christian. The flat top of the mound was under cultivation, and a very careful search of the surface showed no sign of pottery or charcoal remains. This tends to indicate that the mound is not, correctly speaking, a rath, but a burial monument in which most probably other graves still exist.

BALLYLOUGH CRANNOG.—As requested by the Committee, the Hon. Secretary, by arrangement with, and by kind permission of Colonel Traill, D.L., visited this site in August. The various annals and other records make frequent mention of Ballylough, otherwise Loughtown. During the Norman occupation it was held under the Earldom of Ulster by the Savages, who with their neighbours, the de Mandevilles, were the chief holders of land in the Route. At a later date the annals refer to these lands as being in the possession of the family of McQuillan, which is almost undoubtedly a corruption of the Irish MacUghlin (son of little Hugh) derived from a Hugh de Mandeville. It is probable that the de Mandevilles combined the Savage estate with their own by intermarriage, but no positive evidence is as yet forthcoming.

Several mentions occur showing that in the 16th century the McQuillans lived in a crannog at Ballylough, where also a castle of apparently this period was built, the piel tower of which still remains. Early in the 17th century, some time after the expulsion of the McQuillans by the McDonnells, this property was held under the Earls of Antrim by a branch of the Stuarts

of Ballintoy, who in turn sold it to a cadet of the old Fifeshire family of Traill of Blebo in Fife, the present owners. Colonel Traill's grandfather conceived the idea of draining the lake by cutting a deep channel from it to the river Bush. In cutting this trench a considerable number of relics were found, including a large oak corracle, mediaeval pottery, a beautiful chain of silver filagree beads, and near the castle a number of coins of the 15th and 16th centuries. A few of these relics remain at Ballylough, but the exact site of the crannog is uncertain. The site of the old lake and its immediate surroundings are so overgrown with trees and brambles that it is difficult to get any clear view of the general contour. So far as tradition relates, the corracle and pottery were found at a spot where there is no apparent evidence of a crannog having existed, and so far as can be seen, on what was near the edge of the lake. There is a circular entrenched group of trees known as "the decoy plantation," which would have been surrounded by the lake, and which has, taken in conjunction with the surroundings, every appearance of a crannog, and it is most probable that it is here that the crannog site remains undisturbed. However, it is all so overgrown with trees and undergrowth that its investigation seems practically impossible.

Sir Charles Brett referred in sympathetic terms to the accident that had befallen the recently-appointed President of the Society, Mr. Henry Riddell, M.I.Mech.E., but rejoiced to say that he was rapidly returning to his normal health and vigour. He regretted that circumstances over which the Section had no control had prevented any important investigations being carried out during the year, but referred with pleasure to the increase in the membership of the Section, to within a very few of 100 members, and of the satisfactory state of the funds. He hoped that during the coming year the Archaeological Section would continue to give a good account of itself.

Canon Carmody made an eloquent appeal to the meeting on behalf of the investigation and preservation of the Celtic

ecclesiastical remains on Mahee Island, upon the history of which the late Bishop Reeves had thrown so much light. He admitted that to carry out the work in a proper manner a considerable sum of money would be necessary, but he thought that the funds at the disposal of the Section could not be better spent.

Mr. W. B. Burrowes heartily supported Canon Carmody's appeal. He said that if more money were required than the Section could afford, he was certain that the amount could easily be raised by subscription, and on his suggestion, the question was referred to the Executive Committee for consideration.

The election of office-bearers for the year was proceeded with, with the following results :—

Chairman,	Sir Charles Brett, LL.D.
Hon. Treasurer,	Mr. Henry Riddell, M.E. (President of the Society).
Hon. Secretary,	Mr. H. C. Lawlor, M.R.I.A.

Executive Committee :—Sir Charles Brett, LL.D. ; Mr. Henry Riddell, M.E. (ex-officio) ; Mr. H. C. Lawlor, M.R.I.A ; Mr. Arthur Deane, M.R.I.A. (ex-officio) ; Rev. Canon Carmody, M.A. ; Mr. H. R. Lepper, M.A., F.R.Hist.S. ; Mr. Thomas Edens Osborne, F.R.S.A.I. ; Mr. W. B. Burrowes, F.R.S.A.I. ; Mr. Fergus Greeves, Rev. William Adams, M.A. ; Mr. Alec Wilson, J.P., M.R.I.A. ; Mr. Godfrey Ferguson, J.P., C.E.

APPENDIX

LIST OF LECTURES.

1920.

5th October. *In Assembly Minor Hall.*
"Many Inventions: a Study in Natural History," by Professor J. Arthur Thomson, M.A., LL.D., F.R.S.E.

9th November. *In Museum, College Square.*
"The Trend of Evolutionary Thought," by Professor Gregg Wilson, O.B.E., M.A., D.Sc., Ph.D., M.R.I.A.

19th November. *In Queen's University.*
"The Foundation Stones of Matter," by Professor A. W. Stewart, M.A., D.Sc.

26th November. *In Queen's University.*
"The Rise of Radioactivity," by Professor A. W. Stewart, M.A., D.Sc.

3rd December. *In Queen's University.*
"The Transmutation of the Elements and Kindred Problems," by Professor A. W. Stewart, M.A., D.Sc.

10th December. *In Queen's University.*
"Some Problems of Food and Power," by Professor A. W. Stewart, M.A., D.Sc.

14th December. *In Museum, College Square.*
"The Birds of Hillsborough," by Mr. Nevin H. Foster, F.L.S., M.R.I.A., M.B.O.U.

1921.

11th January. *In Assembly Minor Hall.*
"The Wonderland of the Wasps," by Mr. John J. Ward, F.E.S.

14th January. *In Queen's University.*
"The Wanderings of the Groundsel," by Professor James Small, D.Sc., Ph.C., F.L.S.

25th January.	*In Museum, College Square.* "Art and Workmanship," by Mr. Ivor Beaumont, A.R.C.A., M.S.A.
28th January.	*In Queen's University.* "The Erectness of Plants," by Professor James Small.
4th February.	*In Queen's University.* "The Perception of the Invisible." by Mr. R. T. Beatty, M.A., D.Sc.
8th February.	*In Museum, College Square.* "The Decortication of Fibrous Plants, with special reference to Flax Retting and Scutching," by Mr. H. R. Carter.
11th and 25th February.	*In Queen's University.* "The Erectness of Plants" (continued). By Professor James Small.
8th March.	*In Queen's University.* "Dr. Thomas Andrews, the great Chemist and Physicist," by Mr. Henry Riddell, M.E., M.I.Mech.E.

EDUCATIONAL ENDOWMENTS (IRELAND) ACT, 1885.

The Account of the Belfast Natural History and Philosophical Society for the year ended 30th June, 1921.

Dr. | Cr.

CHARGE.

		£	s.	d.
To Balauce as per last Account		£51	7	2
,, Subscriptions		154	17	0
,, Dividends		28	0	1
,, Rents		150	0	0
,, Income Tax Refunded		5	8	0.

LIST OF SECURITIES.

York Street Flax Spinning Co. 4½ per cent. Debentures	£400	0	0
5 per cent War Loan, 1928-47	305	5	3

Balance against Account on 30th June, 1921	52	15	7
Total,	£442	7	10

DISCHARGE.

	£	s.	d.	£	s.	d.
By Maintenance of Premises, &c.				£8	15	7
,, Rent, Rates and Taxes				29	12	7
,, Salaries				20	0	0
,, Printing and Stationery				216	16	9
,, Postages and Carriage				22	9	8
,, Advertisements				44	18	2
,, Other Payments, viz. :—						
Lantern for Lectures	£6	0	0			
Assistance at Lectures in University	7	2	0			
Assurance	14	12	3			
Audit Fee	1	1	0			
Expenses of Lecturers	21	0	0			
Archaeological Section, Explorations, &c.	47	17	2			
Bank Expenses and Interest	2	2	8			
				99	15	1
Total,				£442	7	10

This Account is furnished in the form required by the Local Government Board. It includes the whole of the Accounts of the Parent Body and the Archaeological Section. The Accounts of the Section follow separately.

We certify that the above is a true Account.
ROBERT M. YOUNG, *Governor.*
HENRY RIDDELL, *Accounting Officer.*
12th day of August. 1921.

I certify that the foregoing Account is correct.
J. MIHY, *Auditor.*
11th day of September, 1921.

IN ACCOUNT WITH THE BELFAST NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.—1920—1921.

Dr. **ARCHAEOLOGICAL SECTION.** Cr.

EXPENDITURE.	Amount.	REVENUE.	Amount.
April 23, 1919—Exploration at Ballymartin ...	£3 4 0	June 30, 1920—Balance with Parent Society ...	£93 10 10
June 29, 1920—Assistant Secretary	5 0 0	June 30, 1921—Subscription to Sections ...	24 10 0
July 9, 1920—Exploration at Downpatrick ...	25 0 0	Subsidy from Parent Society ...	16 15 0
Secretary for Postages ...	0 6 8	Interest allowed	2 10 0
Oct. 18, 1920—Share of Printers' Bill ...	8 6 6		
Nov. 4, 1920—Exploration at Downpatrick ...	16 10 6		
,, 17, 1920—Secretary for Postages, &c. ...	6 0 0		
Treasurer, Cost of Collections, Postages and Share of L.G.B. Audit Eee	2 6 10		
Balance in hands of Parent Society	70 11 4		
	£137 5 10		£137 5 10

BELFAST NATURAL HISTORY AND PHILOSOPHICAL SOCIETY.

Officers and Council of Management for 1921-22.

President :

HENRY RIDDELL, M.E., M.I.Mech.E.

Vice-Presidents :

SIR CHARLES BRETT, LL.D.
S. W. ALLWORTHY, M.A., M.D., F.C.S.
PROF. GREGG WILSON, O.B.E., M.A., D.SC., PH.D., M.R.I.A.
ROBERT M. YOUNG, M.A., M.R.I.A., J.P.
J. M. FINNEGAN, B.A., B.SC.
WILLIAM SWANSTON, F.G.S.

Hon. Treasurer :

HENRY RIDDELL, M.E., M.I.Mech.E.

Hon. Librarian.

ROBERT M. YOUNG, M.A., M.R.I.A., J.P.

Hon. Secretary :

ARTHUR DEANE, M.R.I.A..

Council :

SIR CHARLES BRETT, LL.D. T. EDENS OSBORNE, F.R.S.A.I. S. W. ALLWORTHY, M.A., M.D., F.C.S. WILLIAM FAREN, F.R.S.A.I. ARTHUR DEANE, M.R.I.A.	*Retire 1922.*
W. B. BURROWS, F.R.S.A.I. COUNCILLOR E. J. ELLIOTT. H. C. LAWLOR, M.R.I.A. WILLIAM SWANSTON, F.G.S. PROFESSOR GREGG WILSON, D.SC., M.R.I.A.	*Retire 1923.*
JOHN M. FINNEGAN, B.A., B.SC PROFESSOR W. B. MORTON, M.A. HENRY RIDDELL, M.E., M.I.Mech.E. ROBERT M. YOUNG, M.A., M.R.I.A. PROFESSOR A. W. STEWART, M.A., D.SC.	*Retire 1924.*

EXCHANGES.

ABO—Acta Academial Aboensis.

BASEL (Switzerland)—Verhandlungen der Naturforchenden Gesellschaft in Basel, 1919-20.

BELFAST—Proceedings of the Belfast Naturalists' Field Club, 1920-21.

BERGEN (Norway)—Publications of the Bergen Museum

BIRMINGHAM—Proceedings of the Birmingham Natural History and Philosophical Society.

BOLOGNA—Publications of the Science Academy of the Institute of Bologna.

BRIGHTON—Annual Report and Proceedings of the Brighton and Hove Natural History Society, 1920.

BROOKLYN—Bulletins of the Brooklyn Museum.

BRUSSELS—Annals de la Societe Royale Zoologique et Malacologique de Belgique, 1914-1920.

,, Bulletin de la Sociètè Royale de Botanique de Belgique.

BUENOS AIRES—Anales del Museo Nacional del Historia Natural.

BUFFALO—Bulletins of the Buffalo Society of Natural Sciences.

CALIFORNIA—Publications of the University of California.

CALCUTTA—Memoirs of the Geological Survey of India.

,, Records of the Geological Survey of India.

CAMBRIDGE (U.S.A.)—Bulletins of the Cambridge Museum of Comparative Zoology.

CAMBRIDGE—Proceedings of the Cambridge Philosophical Society.

CARDIFF—Transactions of the Cardiff Naturalists' Society, 1917-18.

CARDOVA—Boletin de la Academia National de Ciencias.

CHICAGO—Publications of the Field Museum of Natural History.

CHRISTIANA—Forhandlinger Vidrskapssilskapet I Kristianna.

CINCINNATI—Publications of the Lloyd Library.

COLORADS SPRINGS—Publications of the Colorado College.

DUBLIN—Proceedings of the Royal Dublin Society.

EDINBURGH—Proceedings of the Royal Physical Society.

,, Proceedings of the Royal Society of Edinburgh, 1918-19.

,, Transactions and Proceedings of the Botanical Society, Edinburgh.

ESSEX—The Essex Naturalist. Vol. XIX, Part 4.

INDIANA—Proceedings of the Indiana Society of Sciences, 1918.

LAWRENCE—Bulletins of the University of Kansas.

LIMA (Peru)—Boletin del Cuerpo de de Ingenieros de Minas del Peru

LIVERPOOL—Proceedings of the Liverpool Botanical Society, 1916-18.

LONDON—Quarterly Journal of the Royal Microscopical Society.

,, Memoirs of the Royal Astronomical Society.

,, Quarterly Journal of the Geological Society.

LOUSANNE—Bulletin de la Societe Vaudoise des Sciences Naturelles.

MADISON—Bulletins of the Wisconsin Geological and Natural History Survey.

MADRAS—Report of the Government Museum of Madras, 1919-20.

MELBOURNE—Proceedings of the Royal Society of Victoria.

MEXICO—Anales del Instituto Geologico de Mexico.

MICHIGAN—Report of the Michigan Academy of Science.

NEW HAVEN—Transactions of the Connecticut Academy of Art and Sciences, 1921.

NEW YORK—Annals of the New York Academy of Sciences.

,, The Geographical Review (Monthly).

NICTHEROY—Achivos de escola Superior de Agricultura e Medica Veterinaria, 1920.

OHIO—The Ohio Journal of Science.

OTTAWA—Memoirs of the Canadian Geological Survey.

,, Memoirs of the Geological Survey of Canada, Department of Mines.

,, Publications of the Canadian Department of Agriculture.

PADOVA (Italy)—Atti della Accademia Scientifica.

PHILADELPHIA—Proceedings of the Academy of Natural Sciences of Philadelphia.

,, Proceedings of the American Philosophical Society.

PISA—(Italy)—Atti della Societa Tescana di Scienze Naturali.

PUSA—Reports of the Agricultural Research Institute, 1919-20.

RENNES—Bulletin de la Societe Geologique.

RIO DE JANEIRO—Report of the National Museum of Brazil.

ROCHESTER (N.Y.)—Proceedings of the Rochester Academy of Science.

SAN FRANCISCO—Proceedings of the California Academy of Science.

ST. LEONARDS—Report of the Hastings and St. Leonards' Natural History Society, 1919-20.

ST. LOUIS—Bulletins of the Missouri Botanical Garden.

,, Public Library Monthly Bulletin and Annual Report.

TACUBAYA—Anuario del Observatorio Astronomico Nacional de Tacubaya.

TORQUAY—Journal of Torquay Natural History Society.

TORONTO—Transactions of the Royal Canadian Institute.

VIENNA—Verhandlungen der Kaiserlich-koniglichen Geologischen Reichsanstalt, 1914-1918.

,, Verhandlungen der Geologischen Staatsanstalt, 1920.

WASHINGTON—Annual Report of the Smithsonian Institution.

,, Annual Report of the United States National Museum.

,, Bulletins of the Bureau of American Ethnology.

,, Bulletins of the Smithsonian Institution.

WASHINGTON—Contributions from the United States National Herbarium.

,, Proceedings of the United States National Museum.

,, Smithsonian Institution, Miscellaneous Collections.

,, Year Book of the United States Department of Agriculture, 1920.

,, Smithsonian Physical Tables, 7th Edition.

,, Publications of the United States Geological Survey.

YORK—Annual Report of the Yorkshire Philosophical Society, 1920.

ZURICH (Switzerland)—Vierteljahrsschrift der Naturforchenden Gesellachaft in Zurich.

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